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Ice conditions along the Allegheny and Monongahela Rivers as observed on Landsat images, 1972-1985

Lawrence W. Gatto

RIM
RIVER ICE MANAGEMENT

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

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Landsat images were used to map ice distributions along a 72-mile section of the Allegheny River, and the 129-mile-long Monongahela River. River reaches with grey ice and white ice were mapped based on image tones using conventional photointerpretation techniques. Portions of a river that appeared black were mapped as ice free, although thin, transparent ice could also appear black. Grey tones were produced by ice that varied from patches of solid or fragmented ice with large open-water areas, to floes, pans, slush, or thin ice mixed with open areas. A white tone was produced by thick ice or snow-covered ice with very small or no open areas. Ice that produced grey tones was more frequent than ice that produced a white tone. Ice was observed on the Allegheny River during 10 of the 13 winters from 1972 to 1985, with the most severe ice conditions in 1976-77 when 100% of the river showed evidence of some ice cover, and 89% of the river was covered with white ice. The Monongahela River had ice during 7 winters. Grey ice and white ice were observed covering the entire Monongahela River during the 1983-84 winter. During 1976-77, grey and white ice covered 94%.

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PREFACE

This report was prepared by Lawrence W. Gatto, Geologist, Geological Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was funded by the Office of the Chief of Engineers, Directorate of Civil Works, under the River Ice Management (RIM) Program, CWIS 32228, *Remote Ice Monitoring System*.

The author thanks Eleanor Huke for setting up the base maps, for drafting the final maps, and for preparing the location map; Matthew Pacillo for preparing the graphs; Donna Harp and Jacqueline Castor for repeated typing of this manuscript with its numerous tables; Mark Hardenberg for technical editing, which included excellent suggestions on report format and wording; and Duane Eppler and Michael Bilello for technical reviews of the manuscript. Both reviewers suggested many changes that improved the manuscript, making it far more readable.

Air temperature data were obtained from the National Weather Service, water temperature data from the Ohio River Sanitation Commission and discharge data from the U.S. Geological Survey.

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CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

These conversion factors include all the significant digits given in the conversion tables in the ASTM *Metric Practice Guide* (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
$foot^2$	0.09290304	$meter^2$
$foot^3$/second	0.02831685	$meter^3$/second
mile	1609.347	meter
degrees Fahrenheit	$t°C = (t°F - 32)/1.8$	degrees Celsius

Ice Conditions Along the Allegheny and Monongahela Rivers as Observed on Landsat Images, 1972–1985

LAWRENCE W. GATTO

INTRODUCTION

In the northern United States, ice can delay or stop winter navigation and cause unexpected emergencies. Because of its responsibility for providing safe and reliable navigation routes, the Corps of Engineers is analyzing river ice and investigating structural and operational solutions to ice problems on rivers as part of its River Ice Management (RIM) Program.

One element of the RIM Program was the collection of data on past ice conditions along the Ohio, Allegheny, Monongahela and Illinois Rivers from ground observations, aerial photographs and video tapes, and Landsat images. Ice observations by the Corps of Engineers and National Weather Service from ground sites cover only those river reaches visible to people on locks and dams or on the bank, supplemented by the observations of people on boats (Bilello et al., in press); aerial photographs and video tapes were not taken each winter. Satellite imagery, however, is available for entire rivers. Landsat, NOAA-series, and GOES-series images have been used to monitor ice-covered areas on rivers and river-ice breakup (Dey et al. 1977, McGinnis and Schneider 1978, Stefan 1980, Dean 1984), but not along the rivers studied during this project. Based on this previous work and comparisons between Landsat, NOAA, GOES, and DMSP* images, it was evident that Landsat images showed far more detail than the others. Consequently, I used Landsat images for mapping historical ice conditions along the entire navigation channels of the two rivers.

*Defense Meteorological Satellite Program

The ice data are required for developing an ice forecasting model, for evaluating remote sensing systems, and for other projects in the RIM program. The purpose of this report is to summarize ice conditions on the Allegheny and Monongahela Rivers during the winters from 1972–73 to 1984–85 as determined from Landsat images.

Landsat images have several drawbacks for analyzing river ice distributions that change frequently. First, the number of usable images is limited because Landsat groundtracks repeat only every 8 or 9 days and cloud cover frequently obscures the river. Second, river ice is not always apparent on an image nor are all the types and conditions of ice because the Instantaneous Field Of View (IFOV) of the Landsat sensors is sometimes insufficient. Third, the images do not show all the detail that is detected by the Landsat sensors and, consequently, it is not possible to differentiate as many ice types and characteristics as may have been detected. To get full use of the spectral and spatial resolutions of the imagery data, computer analysis of the data would be necessary. Limited funds and time made this approach impractical, since hundreds of images were analyzed during this study.

The areas of study are the 72 miles of the Allegheny River from the end of the navigation channel, 10 miles upstream of Dam 9, to Pittsburgh, Pennsylvania, and the 129-mile-long Monongahela River from the confluence of the West Fork and Tygart Rivers to Pittsburgh (Fig. 1). The Allegheny has eight dams along this reach that divide it into pools; the Monongahela has nine dams (Table 1). Pool lengths vary from 5.9 to 9.8 miles on the Allegheny and 5.8 to 23.8 miles on the Monongahela. Pool surface areas vary from 24.92 to 56.34×10^6 ft^2 along the Allegheny and 17.42 to 81.68×10^6 ft^2 along the Monongahela.

Table 1. River pools to the end of the navigation channel.

Landsat images (path-row)		*Pool no. / length (mi)*	*Pool start and stop points (river miles)*	*Approximate surface area* ($ft^2 X10^6$)*
Landsats 1–3	*Landsats 4,5*			
		Allegheny River		
18–31,18–32,19–31	17–32	1/9.8	River mile 72 to L&D† 9(62.2)	38.81
18–32,19–31,19–32	17–32	2/9.6	L&D 9 to L&D 8 (52.6)	43.09
18–32,19–31,19–32	17–32	3/6.9	L&D 8 to L&D 7(45.7)	34.61
18–32,19–31,19–32	17–32	4/9.4	L&D 7 to L&D 6(36.3)	47.15
18–32,19–31,19–32	17–32	5/5.9	L&D 6 to L&D 5(30.4)	24.92
18–32,19–32	17–32	6/6.2	L&D 5 to L&D 4(24.2)	31.10
18–32,19–32	17–32	7/9.7	L&D 4 to L&D 3(14.5)	56.34
18–32,19–32	17–32	8/7.8	L&D 3 to L&D 2(6.7)	43.22
18–32,19–32	17–32	9/6.7	L&D 2 to Pittsburgh Point (0)	33.05
		Monongahela River		
19–32	17–33	1/13.3	River mile 128.7 to Opekiska L&D (115.4)	31.60
19–32	17–33	2/7.4	Opekiska L&D to Hildebrand L&D (108)	17.58
19–32	17–33	3/6.0	Hildebrand L&D to Morgantown L&D (102)	17.42
18–32,19–32	17–32	4/11.2	Morgantown L&D to L&D 8(90.8)	32.53
18–32,19–32	17–33	5/5.8	L&D 8 to L&D 7(85)	19.91
18–32,19–32	17–33	6/23.8	L&D 7 to Maxwell L&D (61.2)	81.68
18–32,19–32	17–33	7/19.7	Maxwell L&D to L&D 4(41.5)	71.04
18–32,19–32	17–33	8/17.7	L&D 4 to L&D 3(23.8)	71.47
18–32,19–32	17–33	9/12.6	L&D 3 to L&D 2(11.2)	51.34
18–32,19–32	17–33,18–32	10/11.2	L&D 2 to Pittsburgh Point (0)	50.91

*When the water level is at normal pool elevation.
†L&D means lock and dam.

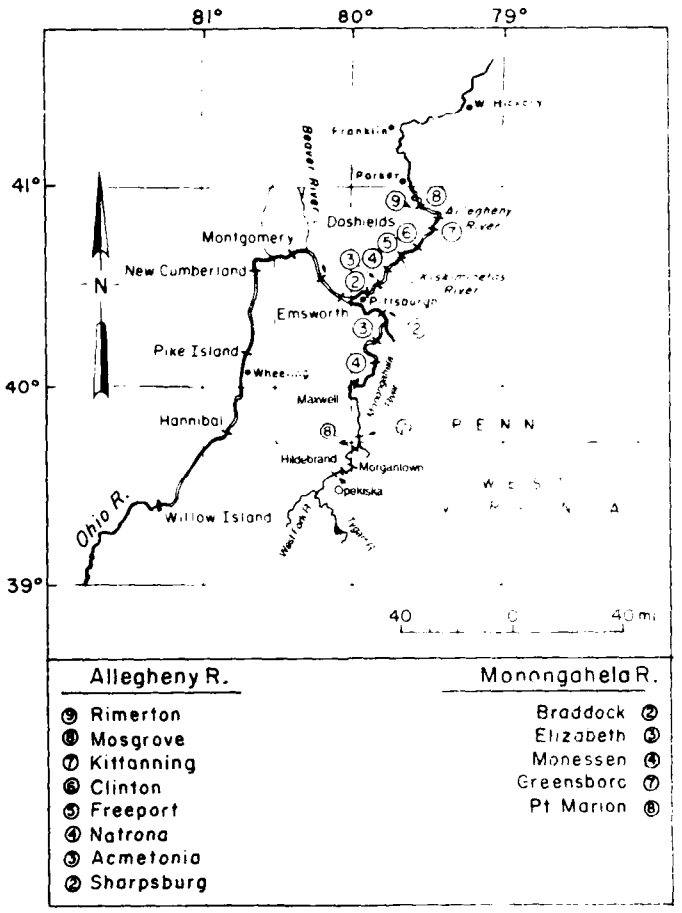


Figure 1. Location map with Corps of Engineers lock and dam sites.

IMAGERY INTERPRETATION AND MAPPING

Each Landsat had two imaging sensors. Landsat 1, 2 and 3 had a Multispectral Scanner (MSS), with an IFOV of approximately 260x260 ft, and a Return Beam Vidicon (RBV), with an IFOV of 262x262 ft on Landsat 1 and 2, and an IFOV of 131x131 ft on Landsat 3. Landsat 4 and 5 have a MSS (same IFOV) and a Thematic Mapper (TM), with an IFOV of 98x98 ft. A visual comparison of imagery in each MSS spectral band showed that more grey tones from river ice are visible to the eye in the 0.6- to 0.7-μm imagery than in the other bands. Consequently, I analyzed 0.6- to 0.7-μm MSS, 0.580- to 0.680-μm RBV (Landsat 1 and 2), 0.505- to 0.750-μm RBV (Landsat 3), and 0.63- to 0.69-μm TM (Landsat 4 and 5) imagery.

Each Landsat image is designated by a path and row number. Four images from Landsat 1, 2 and 3, and one image from Landsat 4 and 5 were used to analyze ice conditions on the Allegheny River (Table 2). Two images from Landsat 1, 2 and 3, and three from Landsat 4 and 5 were required to cover the Monongahela River. Appendix A lists the dates of all Landsat images analyzed during this study. Additional details on Landsat imagery are available in a companion report (Gatto 1988).

Oblique, color aerial photographs and videotapes taken from 1000-3500 ft above the rivers during the winters of 1983–84 and 1984–85 show that ice on the Allegheny and

Table 2. Approximate coverage of each Landsat image.

Landsats 1–3		*Landsats 4 and 5*	
Path—Row	*Approx. river miles*	*Path—Row*	*Approx. river miles*
	Allegheny River		
18–31	55–73 to Allegheny Reservoir		
18–32	0 to 90	17–32	0 to 85
19–31	25–45 to below Allegheny Reservoir		
19–32	0 to 40–65		
	Monongahela River		
18–32	0 to 100–105	17–32	0 to 103
19–32	0 to 129	17–33	95 to Tygart Lake
		18–32	0 to 10

Table 3. Ice conditions as observed from a low-altitude aircraft (from Gatto and Daly 1986).

	Description
[1] Open water	River is ice-free; no ice apparent.
[2] Solid ice cover	River is completely covered (100%) with ice; no individual ice pans, blocks, or chunks are visible; ice may be snow-covered.
[3] Solid ice cover with open-water areas	River is partially covered with solid ice (as described above) but has open (ice-free)areas.
[4] Fragmented ice cover	River is completely covered (100%) with ice that has distinct, variably sized, individual ice pans, blocks, or chunks.
[5] Fragmented ice cover with open-water areas	River is partially covered with fragmented ice (as described above) but has open (ice-free) areas.
[6] Ice floes or frazil slush and pans	River is primarily open (ice-free) with floating ice floes, slush, or pans.

Monongahela Rivers varies considerably in its characteristics, but in general can be visually classified into six ice conditions (Table 3). The IFOV and spectral resolution of Landsat sensors are insufficient to show the differences among these six conditions, although Landsat TM images show much more detail than the MSS and RBV images. In addition, Foster et al. (1978) report that it is often difficult to distinguish different ice types on Landsat images because different ice may have the same appearance or spectral signature.

The primary characteristics that influence grey tones for river ice observed on Landsat images are ice thickness, snow cover and mixtures of river surface types, some of which are smaller in area than the IFOV of Landsat sensors. This is important because the principal source of error in this

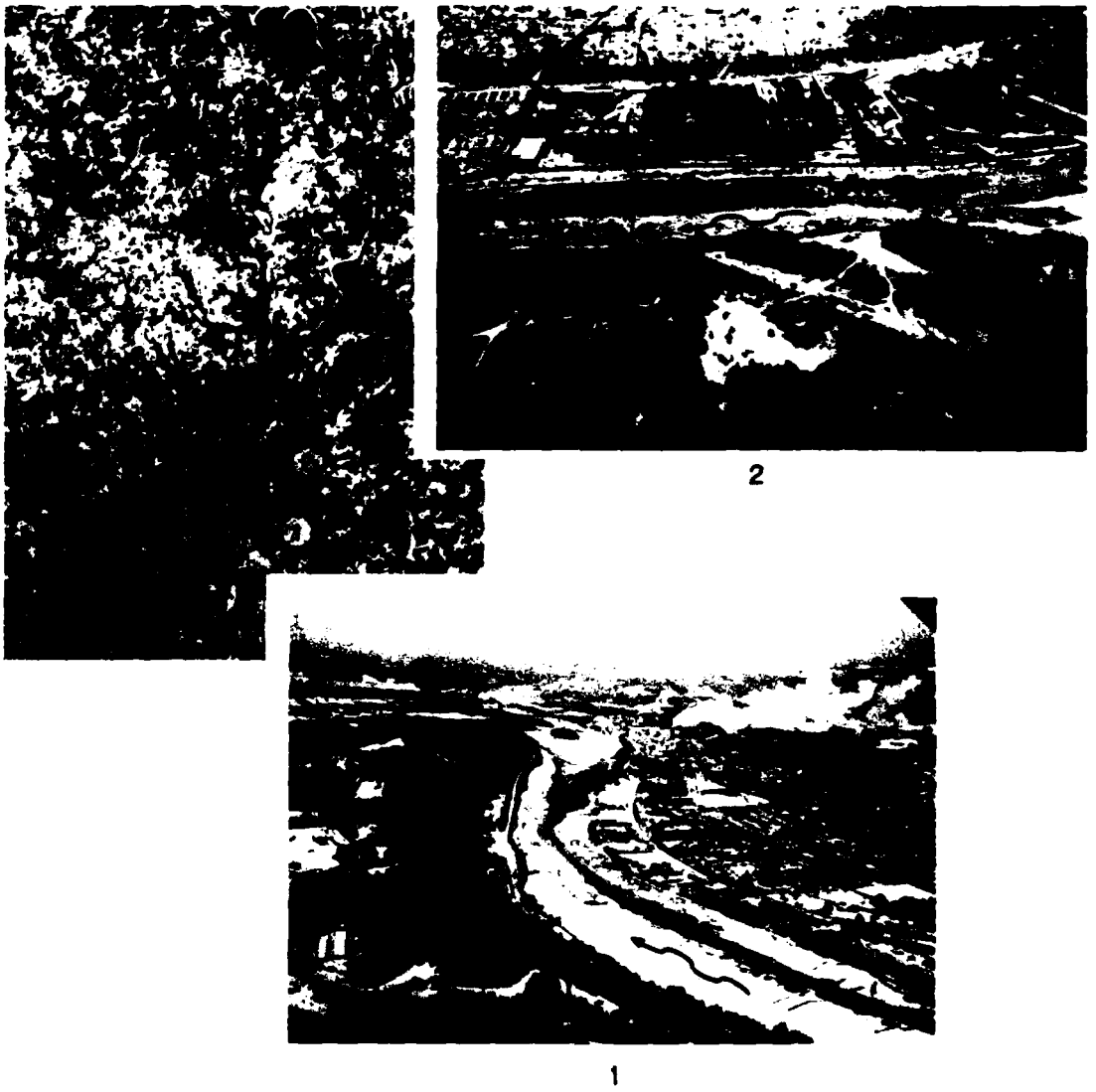


Figure 2. Landsat image of the Allegheny River taken 22 January 1984; low-altitude photographs taken on 20 January 1984. On the Landsat image, river flow runs from top to bottom.

study arises from the erroneous inferences one could make regarding the ice conditions that Landsat grey tones represent. For example, thin ice in one scene may be transparent, appear black, and be classified as open water. This same ice cover viewed after a light snowfall would appear white.

When I viewed Landsat images (9- by 9-in. black and white film positives) of the rivers on a light table with a 7–10 power magnifier, reaches of the rivers appeared as black, grey or white. Textures and patterns within the tones sometimes were apparent, but the subtleties that differentiate the six ice conditions (Table 3) were not obvious.

To determine which types of river ice produced these different tones, textures and patterns, I compared ice conditions shown on aerial photographs and videotapes taken on dates as close as possible to those for which Landsat images are available during the 1976–77, 1977–78, 1983–84 and 1984–85 winters. These comparisons show that when the river appeared black on an image and had no discernible textures and patterns, the river was open (ice free). It is possible, however, that thin, transparent ice that appears black from above covered part or all of the river in some instances. Thin ice such as this cannot be distinguished from open water in Landsat

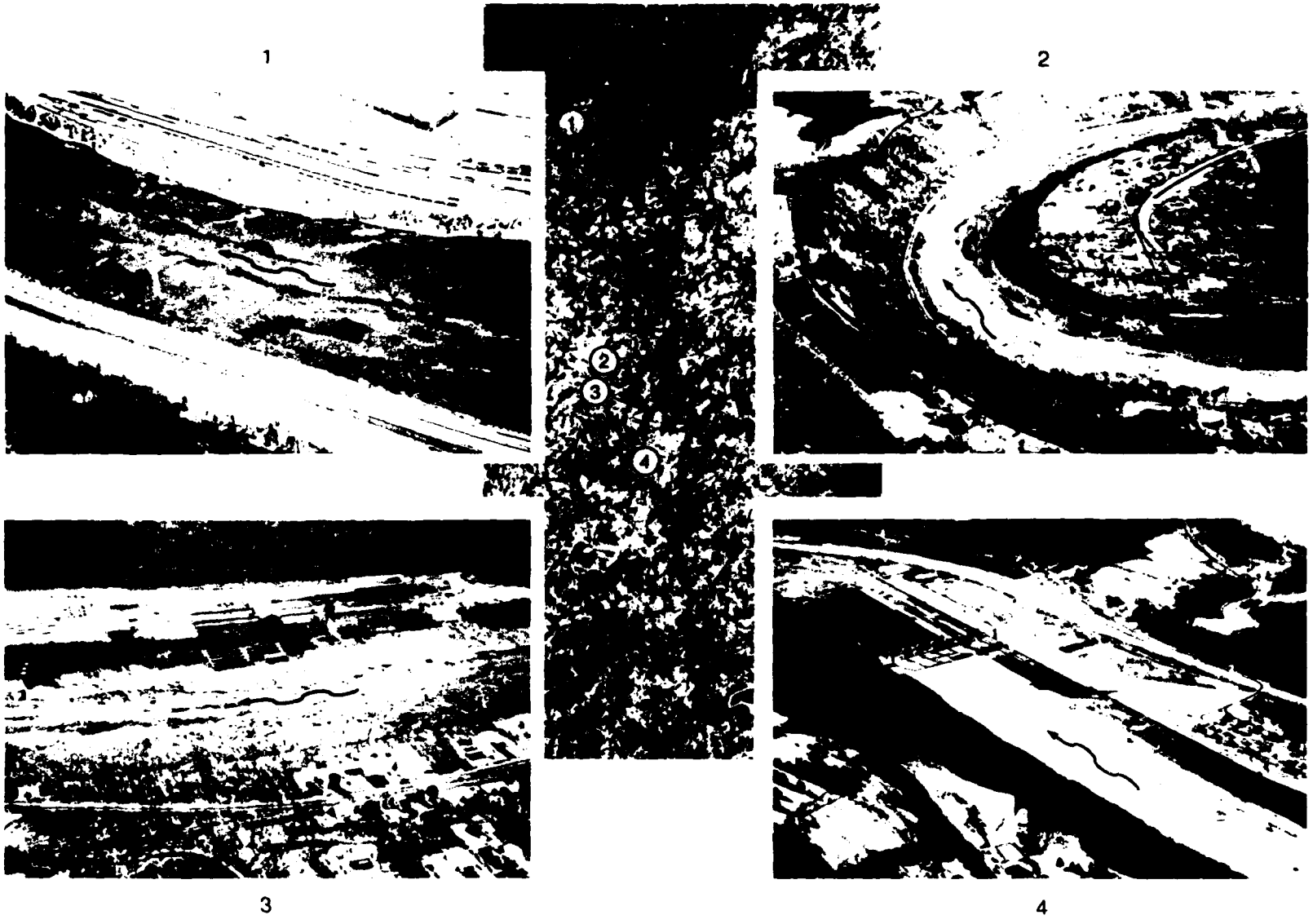


Figure 3. Landsat image of the Monongahela River taken 22 January 1984; low-altitude photographs taken on 20 January 1984. On the Landsat image, river flow runs from bottom to top.

images. During some of the low-altitude aircraft flights in 1983–84, the only way transparent (black) ice was apparent to the eye was when a barge went through the ice and made visible cracks.

Ice conditions that appear grey on Landsat images vary from fragmented ice (usually thin) with large open areas to ice floes, pans, or slush mixed with open areas. The grey tone usually had a patchy or mottled appearance or showed textures or patterns. This grey ice should not be confused with the term "grey ice" as applied to sea ice (WMO 1970).

When the river appeared white (or nearly white), sometimes with discernible textures or patterns, ice conditions varied from solid or fragmented ice (usually thicker than grey ice) with no open water to ice with scattered open water areas that are smaller than Landsat's IFOVs. These openings are fewer than those that occur where a grey tone is observed. A white tone could also mean that the river ice was snow-covered. A navigation track in white ice appears black if the track is ice-free. More commonly, the track appears grey because it is filled with slush, brash or floes (Fig. 2 and 3).

The upstream and downstream extent of grey ice and white ice as observed on Landsat images was transferred to base maps (Appendix B). The lengths and areas of open water, grey ice and white ice within each pool were measured and converted to percentages (Appendix C), which were then graphed to show the first, maximum and last ice observed on each pool (Appendix D).

RESULTS

Because Landsat imagery is often the only historical record of river ice conditions, it is not possible to provide an independent check of the imagery analysis. However, river water temperature can be a good indication of the presence or absence of ice. If the river water temperature is at 0°C, a necessary condition for the presence of ice is satisfied. Given the inaccuracies in water temperature measurement, the possible stratification of river water temperature, and other factors, however, one may expect ice to be present when a temperature record indicates river water temperature above 0°C, to some extent. Records of river water temperature (Appendix E) are available at river mile 13.3 about 1 mile downstream of Lock and Dam 3 on the Allegheny River and at river mile 4.5 about 7 miles downstream of Lock and Dam 2 on the Monongahela River. A conservative criterion for the presence of ice was a river water temperature of 0°C, and I assumed that no ice existed when the river water temperature was above 0°C. When Landsat images were available, the image analyses agreed with this water temperature criterion 80.3% of the time (Gatto et al. 1987).

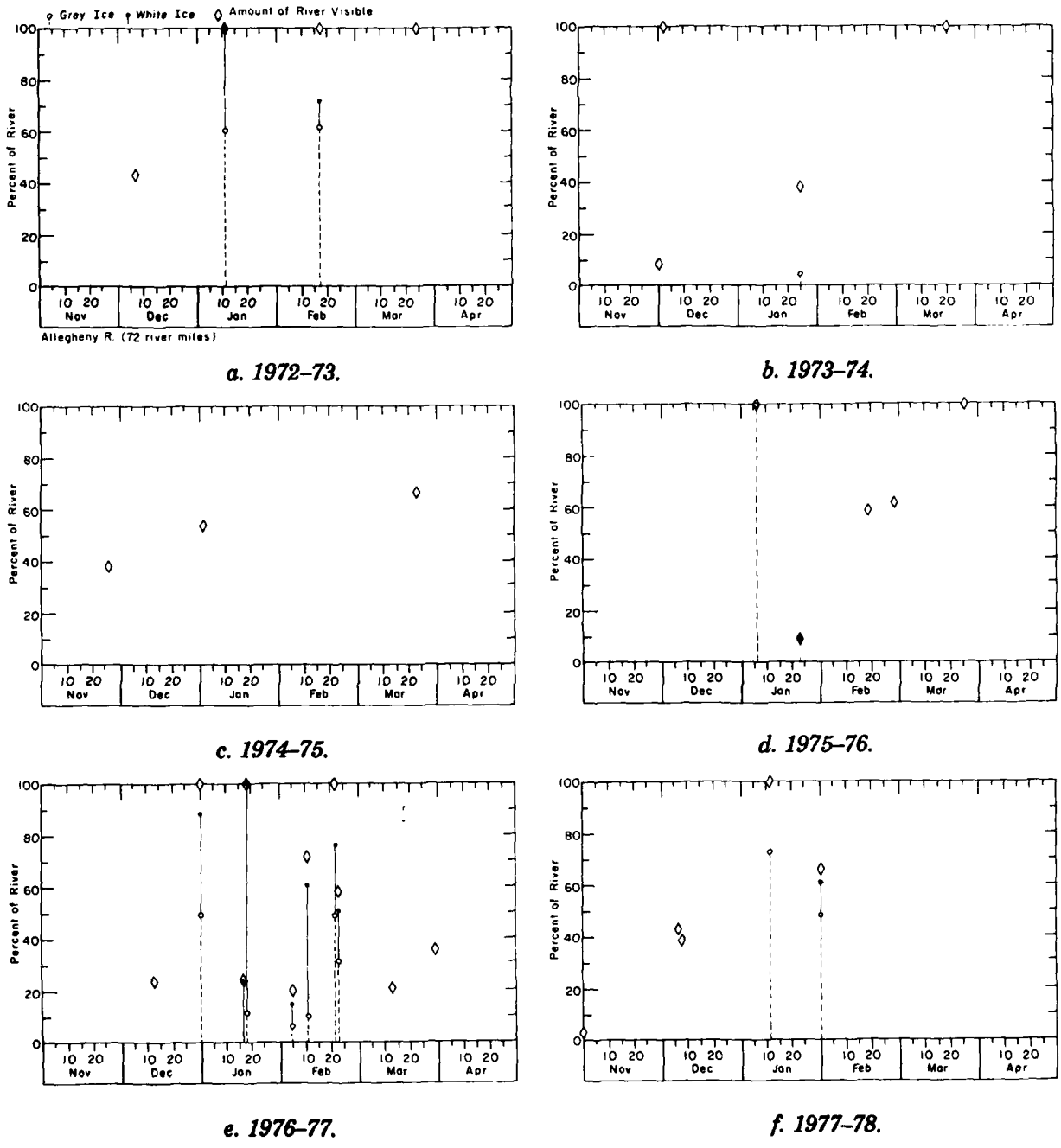
As previously mentioned, one shortcoming of Landsat imagery is the spottiness of coverage. Examination of the river water temperature records (Appendix E) provides one way to quantify this lack of coverage. By examining the water temperature record, the period of the lowest river water temperature for each year could be selected. Often these temperatures were not near 0°C. During this coldest period, 33% of the time Landsat images were not available.

Ice was observed on the Allegheny River with Landsat images during 10 of the 13 winters from 1972 to 1985 (Fig. 4) and during 7 of the 13 on the Monongahela River (Fig. 5). The dates cited in this report are the dates when ice was observed on Landsat images. Note that dates of Landsat observations do not necessarily coincide with dates when ice on both rivers actually first occurred, was at its maximum, or last occurred.

1972–73

When ice was observed on Landsat images in 1972–73 (Fig. 4 and 5), air temperature was -10 to -15°C in the Pittsburgh area, water temperature was at or near freezing and discharges were low (Fig. E1). On the Allegheny River, the first ice and the maximum extent of ice were observed on 11 January when all of the study area had grey ice and white ice (Fig. B1a, Table 4). Ice was last observed on 17 February when 62% of the river had a grey ice cover and 10% had white. Only the Lock and Dam 7 pool (pool 3) appeared black on this date (Fig. B1a and D1a).

On the Monongahela River, ice first observed on the 11 January Landsat image was grey and covered only 3% of the river (Fig. 5, Table 5). On 17 February, ice covered 35% of the river at its maximum extent (Fig. B1b and D1b).



a. 1972–73.

b. 1973–74.

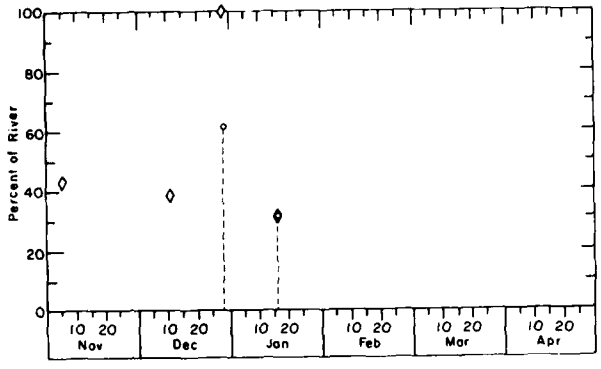
c. 1974–75.

d. 1975–76.

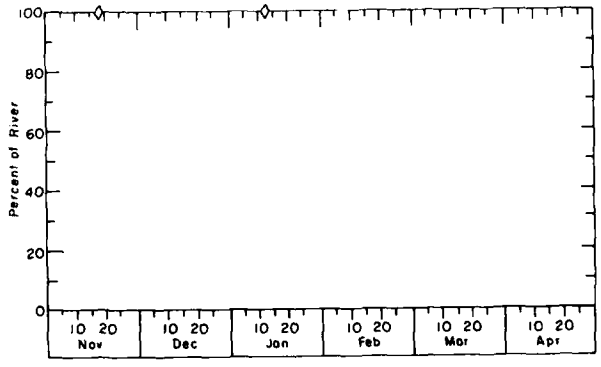
e. 1976–77.

f. 1977–78.

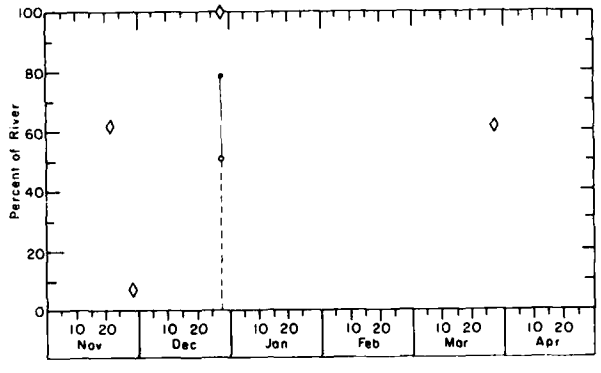
Figure 4. Areal extent of ice observed on Landsat images from 1972 to 1985, Allegheny River.



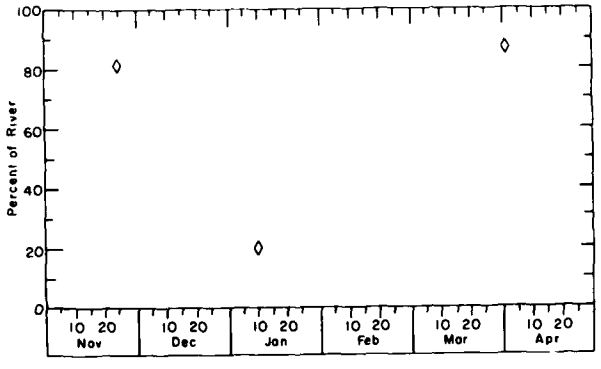
g. 1978–79.



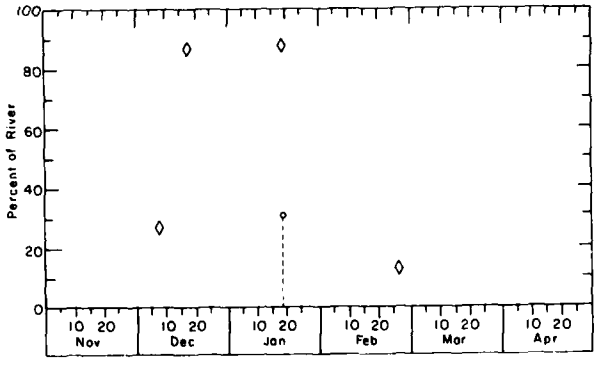
h. 1979–80.



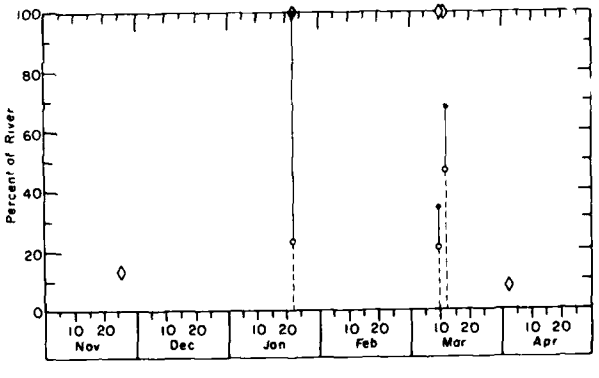
i. 1980–81.



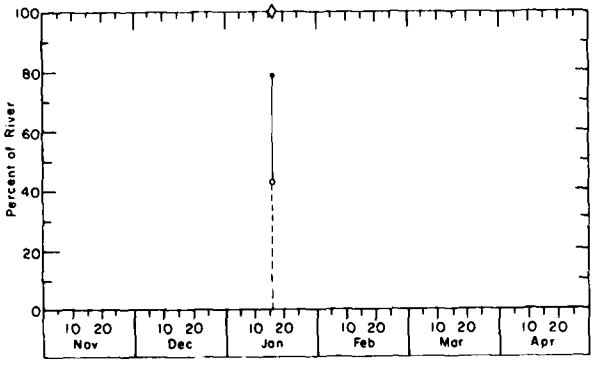
j. 1981–82.



k. 1982–83.

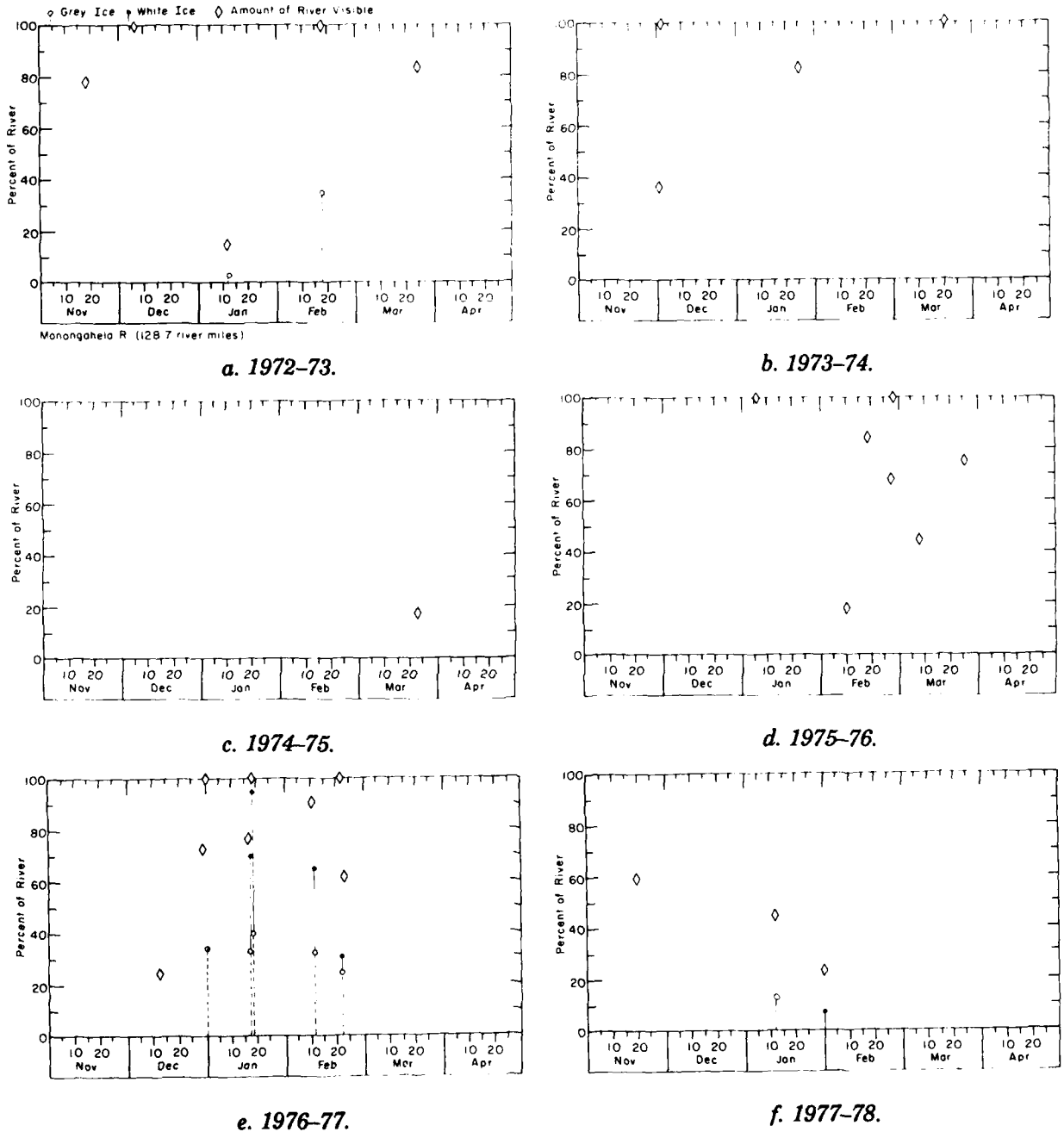


l. 1983–84.



m. 1984–85.

Figure 4 (cont'd).



a. 1972–73.

b. 1973–74.

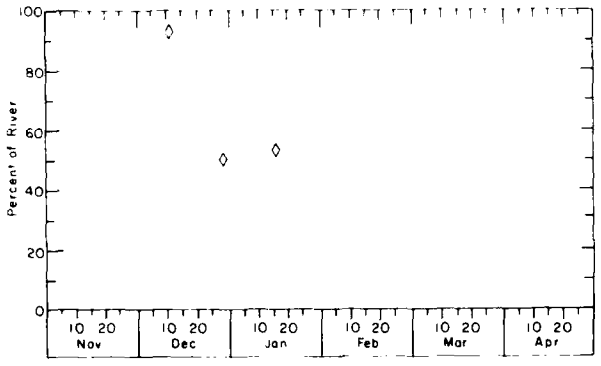
c. 1974–75.

d. 1975–76.

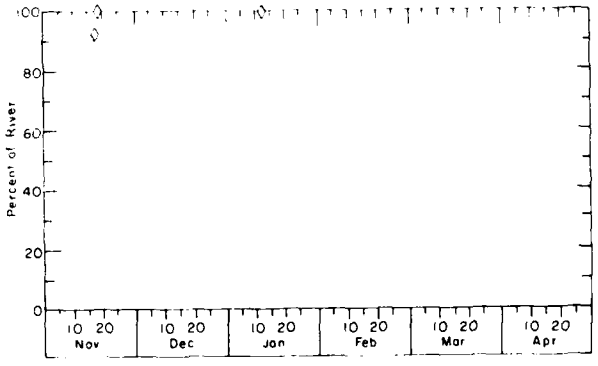
e. 1976–77.

f. 1977–78.

Figure 5. Areal extent of ice observed on Landsat images from 1972 to 1985, Monongahela River.



g. 1978–79.



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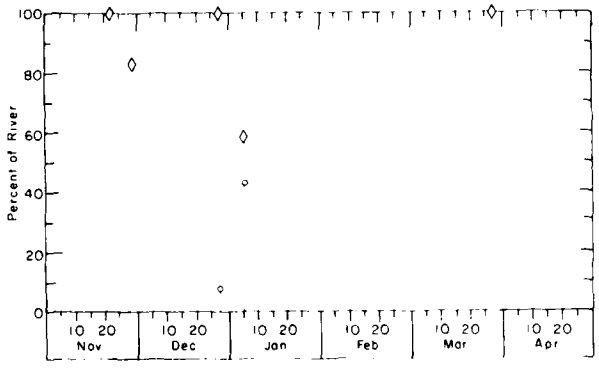

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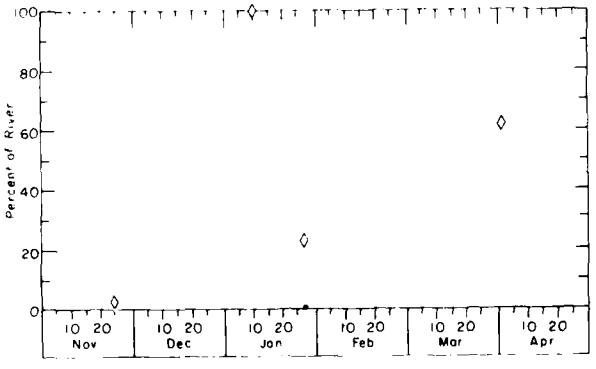

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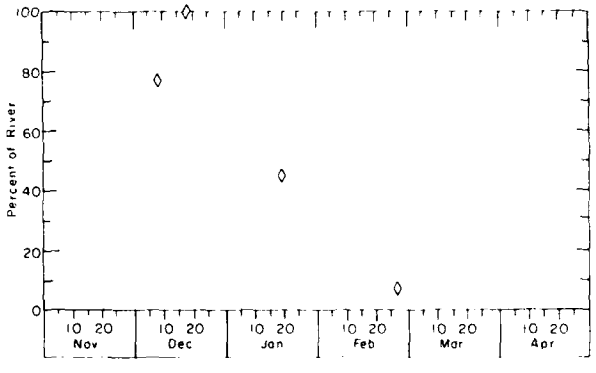

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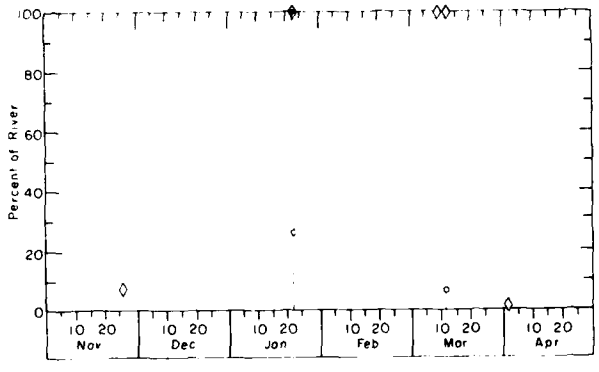
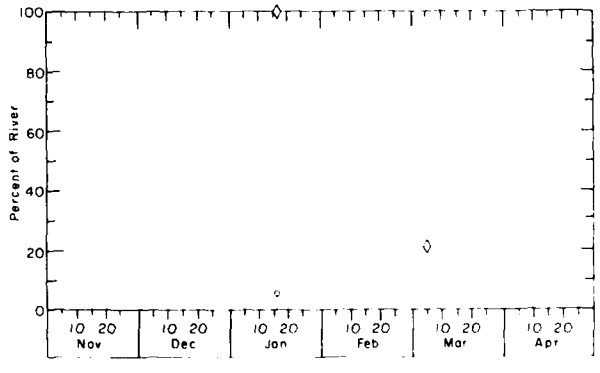


l. 1983–84.



m. 1984–85.

Figure 5 (cont'd).

Table 4. Summary of ice distributions (%) as observed on Landsat images (except where noted), Allegheny River (percentages rounded to nearest whole percent).

	Date	Amount of river visible	Black (ice free)	Grey ice	White ice
		1972-73			
First ice and maximum extent of ice	11 January	100	0	60	40
Last ice	17 February	100	28	62	10
		1973-74			
Ice observed once	25 January	38	34	4	0
		1975-76			
First ice and maximum extent of ice	6 January	100	0	100	0
Last ice	23 January	8	0	0	8
		1976-77			
First ice	31 December	100	12	49	39
Maximum extent of ice	18 January	100	[illegible]	11	89
Last ice	23 February	58	8	31	19
		1977-78			
First ice and maximum extent of ice	12 January	100	27	73	0
Last ice	31 January	66	4	49	13
		1978-79			
First ice and maximum extent of ice	29 December	100	39	61	0
Last ice	16 January	31	0	31	0
		1980-81			
Ice observed once	28 December	100	22	51	27
		1982-83			
Ice observed once	19 January	87	57	30	0
		1983-84			
First ice*	29 December	10	2	—	—
Maximum extent of ice	22 January	100	0	23	77
Last ice	12 March	100	32	47	22
		1984-85			
First ice and maximum extent of ice (ice observed once)	16 January	100	21	42	37
Last ice**	24 February	10	10	—	—

*Based on aerial observations (Gatto and Daly 1986); 3% of the river was covered with solid ice, 5% with solid ice with open areas.

**Based on videotape analysis (Gatto et al. 1986); 0.1% of the river was covered with ice floes or frazil slush and pans

Table 5. Summary of ice distributions (%) as observed on Landsat images (except where noted), Monongahela River (percentages rounded to nearest whole percent).

	Date	*Amount of river visible*	*Black (ice free)*	*Grey ice*	*White ice*
		1972–73			
First ice	11 January	15	12	3	0
Maximum extent of ice observed and last ice	17 February	100	65	35	0
		1976–77			
First ice	31 December	100	66	34	0
Maximum extent of ice	18 January	100	5	40	55
Last ice	22 February	99	69	24	6
		1977–78			
First ice and maximum extent of ice	12 January	45	33	12	0
Last ice	31 January	23	16	0	7
		1980–81			
First ice	28 December	100	92	8	0
Maximum extent of ice and last ice	5 January	59	16	43	0
		1981–82			
Ice observed once	27 January	23	22	1	0
		1983–84			
First ice*	29 December	5	1	—	—
Maximum extent of ice	22 January	100	0	26	74
Last ice	12 March	100	94	6	0
		1984–85			
First ice	16 January	100	94	6	0
Maximum extent of ice**	4 February	51	9	—	—
Last ice**	24 February	51	51	—	—

*Based on aerial observations (Gatto and Daly 1986); 4% of the river was covered with ice floes or frazil slush and pans.

**Based on videotape analysis (Gatto et al. 1986); 4 February—6% of the river was covered with solid ice, 1% with solid ice with open areas, 8% with fragmented ice, 20% with fragmented ice with open areas, 7% with ice floes or frazil slush and pans; 24 February—0.3% of the river was covered with ice floes or frazil slush and pans.

1973–74

Ice was observed once on a Landsat image. The ice was apparent only on the upstream section of the Lock and Dam 9 pool (Fig. B2 and D2) of the Allegheny River on 25 January. It was grey ice and it covered 4% of the river (Table 4).

1975–76

On 6 January, the first and maximum extent of ice on the Allegheny River was seen on a Landsat image (Table 4). It was grey ice that covered 100% of the river. The ice last observed was white ice that covered 8% of Lock and Dam 8 pool on 23 January (Fig. B4 and D3).

1976–77

River water temperatures (Fig. E5) dropped steadily during December and reached the freezing point early that month. On 1 January a cold period began that lasted 5 to 6 weeks. The average daily air temperature during this period remained below freezing and discharge was low.

Ice first observed on the Allegheny and Monongahela Rivers consisted of grey ice and white ice (Fig. B4) on 31 December (Fig. 4 and 5) and covered 88 and 34% of the rivers, respectively (Tables 4 and 5). The maximum extent of ice on both rivers was observed on 18 January. A mix of white ice and grey ice covered all of the Allegheny River and 95% of the Monongahela. The ice last observed covered 50% of the Allegheny River on 23 February and 30% of the Monongahela.

1977–78

The first ice and the maximum extent of ice were observed on 12 January on both rivers (Fig. B5). During this time air and water temperatures and discharge were low (Fig. E6). Ice was last observed on 31 January (Fig. 4 and 5; Tables 4 and 5).

1978–79

Ice was observed on only the Allegheny River this winter on 29 December (Fig. 4 and B6, Table 4). It was grey ice that covered 61% of the river. This was also the maximum extent of ice observed on an image this winter. Ice last observed covered 31% of the Allegheny on 16 January (Table 4).

1980–81

Ice on the Allegheny River was observed once on a Landsat image on 28 December when 78% of the river was covered with a mixture of grey ice and white ice (Table 4, Fig. B7a). Only 8% of the Monongahela had grey ice on this date (Table 5, Fig. B7b). Grey ice covered 43% of the Monongahela on 5 January at the maximum extent of ice observed and was not seen on a Landsat image after that date.

1981–82

The only ice observed on an image was grey and covered 1% of the Monongahela River (Table 5) all on the Morgantown Lock and Dam pool (Fig. B8 and D8).

1982–83

Ice was observed with Landsat images only on the Allegheny River. Grey ice covered 30% of the river on 19 January (Table 4) and was most extensive upstream of Lock and Dam 7 (Fig. B9 and D9).

1983–84

During this winter, low-altitude aerial observations and photographs of the lower 7 miles of the Allegheny and for portions of the lower 61 miles of the Monongahela Rivers were acquired on 29 December; 5, 13, 20 and 26 January; and 8 February. Maps of ice distributions were prepared from these aerial data (Gatto and Daly 1986). The following discussion summarizes these ice distributions and the ice conditions observed on Landsat images.

The first observation made was from an aircraft on 29 December (Tables 4 and 5) when solid ice with some open areas covered most of the lower 7 miles of the Allegheny (Tables 4 and 6) and ice floes or frazil slush and pans covered most of the lower 7 miles of the Monongahela (Tables 5 and 6). By 5 January a navigation track filled with floes, slush and pans was apparent in the solid and fragmented ice on the Allegheny. The amount of open water was about the same (Table 6). The lower 7 miles of the Monongahela were open. On 13 January most of the 7 miles of the Allegheny and 40 miles of the Monongahela were covered with floes, slush and pans. No other type of ice was apparent.

Table 6. Summary of predominant ice conditions as observed from an aircraft, 1983–84 (from Gatto and Daly 1986). Ice conditions listed in decreasing order of areal coverage as estimated from maps made from aerial observations, photographs and a videotape.

		Monongahela River			
Dates	*Allegheny River Emsworth Pool*	*Emsworth Pool*	*L&D 2 Pool*	*L&D 3 Pool*	*L&D 4 Pool*
29 December 1983	3,2,1	6,1	–	–	–
5 January 1984	6,3,2,1,5	1	–	–	–
13 January 1984	3,1	6,1	6,1	6,1	–
20 January 1984	3,5,1	6	6	6,5	3,6,2,5,1
26 January 1984	1	6	6	6,5	–
8 February 1984	6,1	1	1	1	–

1–Open water.
2–Solid ice cover.
3–Solid ice cover with open-water areas.
4–Fragmented ice cover.
5–Fragmented ice cover with open-water areas.
6–Ice floes or frazil slush and pans.
See Table 3 for descriptions.

No usable Landsat images were available for December and the first half of January.

Floes, slush and pans still covered the lower 7 miles of the Allegheny on 20 January, but fragmented ice and some open areas were also present. The Monongahela from Pittsburgh to Lock and Dam 3 was covered with floes, slush and pans. Upstream of Lock and Dam 3 to Lock and Dam 4, fragmented ice was also present. Above Lock and Dam 4 to Maxwell Lock and Dam, solid ice and fragmented ice with some open areas were present with the floes, slush and pans (Table 6).

The maximum ice extent observed on a Landsat image was seen on 22 January when grey ice and white ice covered all of the Allegheny and Monongahela Rivers (Fig. 6 and D10). The distribution of grey ice and white ice on the Allegheny (Fig. B10a) and on the Monongahela (Fig. B10b) observed on the 22 January Landsat image generally compares well with that mapped from aircraft data acquired 2 days earlier on 20 January 1984 (Table 6, Fig. 7). Generally, where solid ice and fragmented ice, some with open water areas, were observed from an aircraft, white was mapped from Landsat; where ice floes or frazil slush and pans were seen from the aircraft, grey was mapped from Landsat.

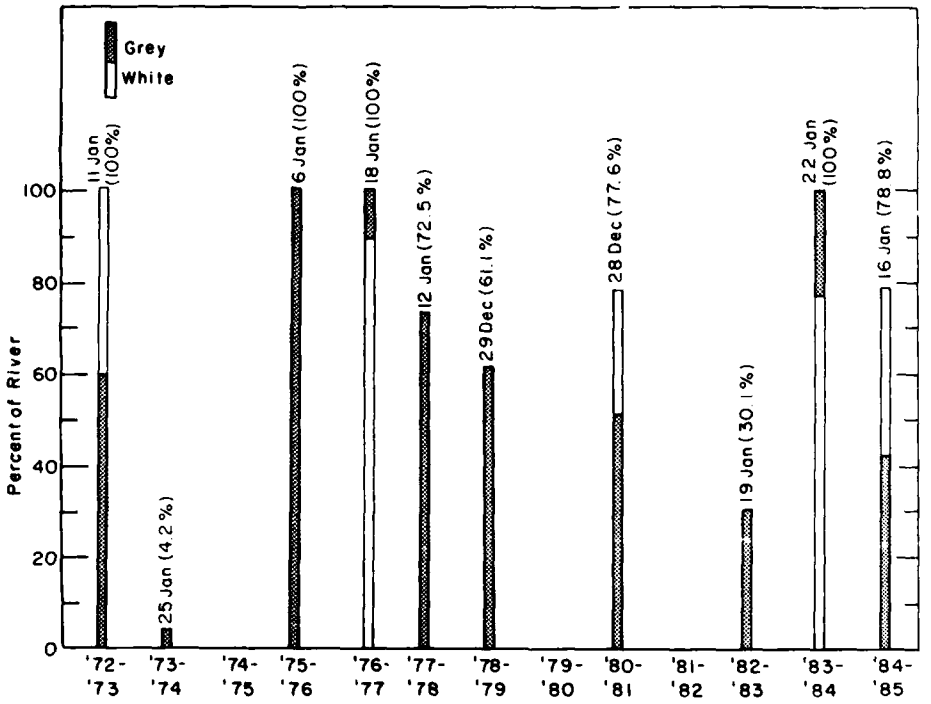
On 26 January, aircraft observations showed that the lower 7 miles of the Allegheny were open, while floes, slush and pans were present on most of the lower 32 miles of the Monongahela. Floes, slush and pans covered most of the lower Allegheny on 8 February, while the lower 43 miles of the Monongahela were ice free.

The last ice observed with Landsat images (Fig. 4 and 5) was grey ice and white ice, covering 69% of the Allegheny and 6% of the Monongahela on 12 March 1984 (Tables 4 and 5).

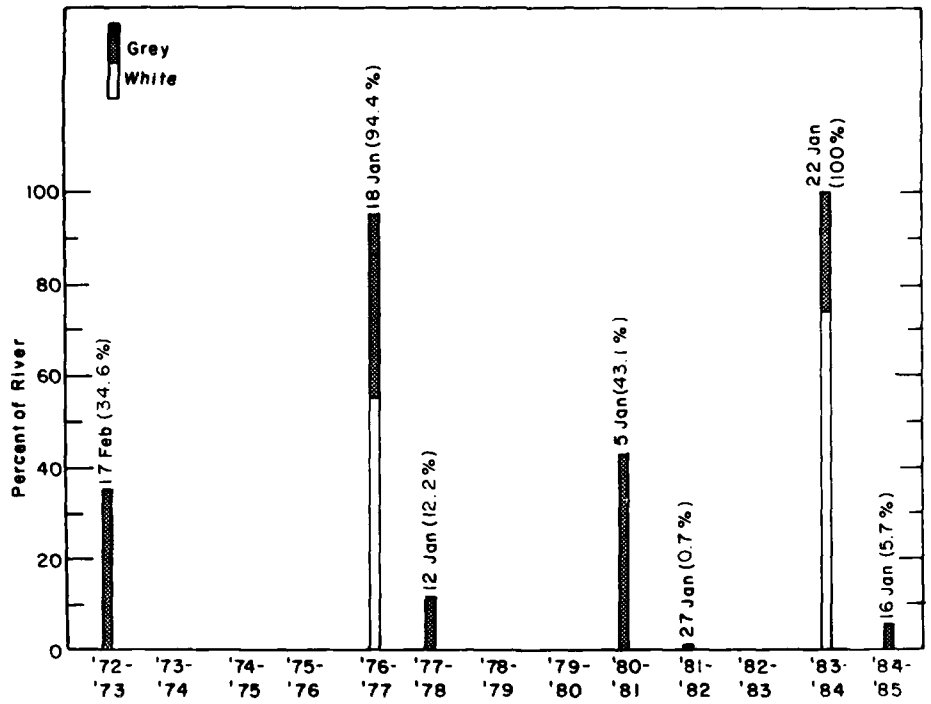
1984–85

During this winter videotapes of ice conditions along portions of the lower 69 miles of the Allegheny River and the lower 66 miles of the Monongahela were taken 19 times from 23 January to 10 March. The results of the analysis of these tapes are given in Gatto et al. (1986) and are summarized here along with Landsat image data.

The first ice as observed with Landsat images was grey and white and covered 79% of the Allegheny and 6% of the Monongahela on 16 January (Tables 4 and 5; Fig. B11). The ice cover on the Allegheny on this date was also at its maximum extent as observed on Landsat images (Fig. 6a). The maximum

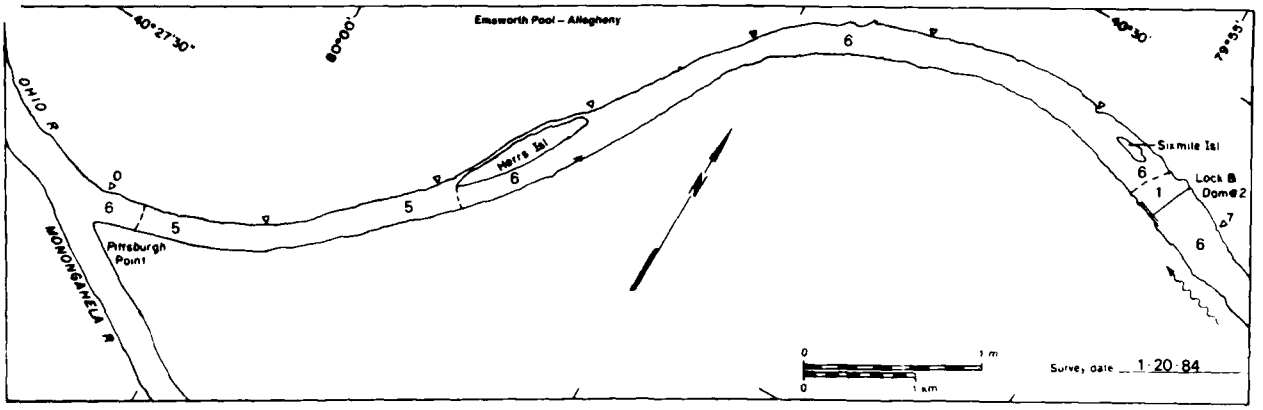


a. Allegheny River.

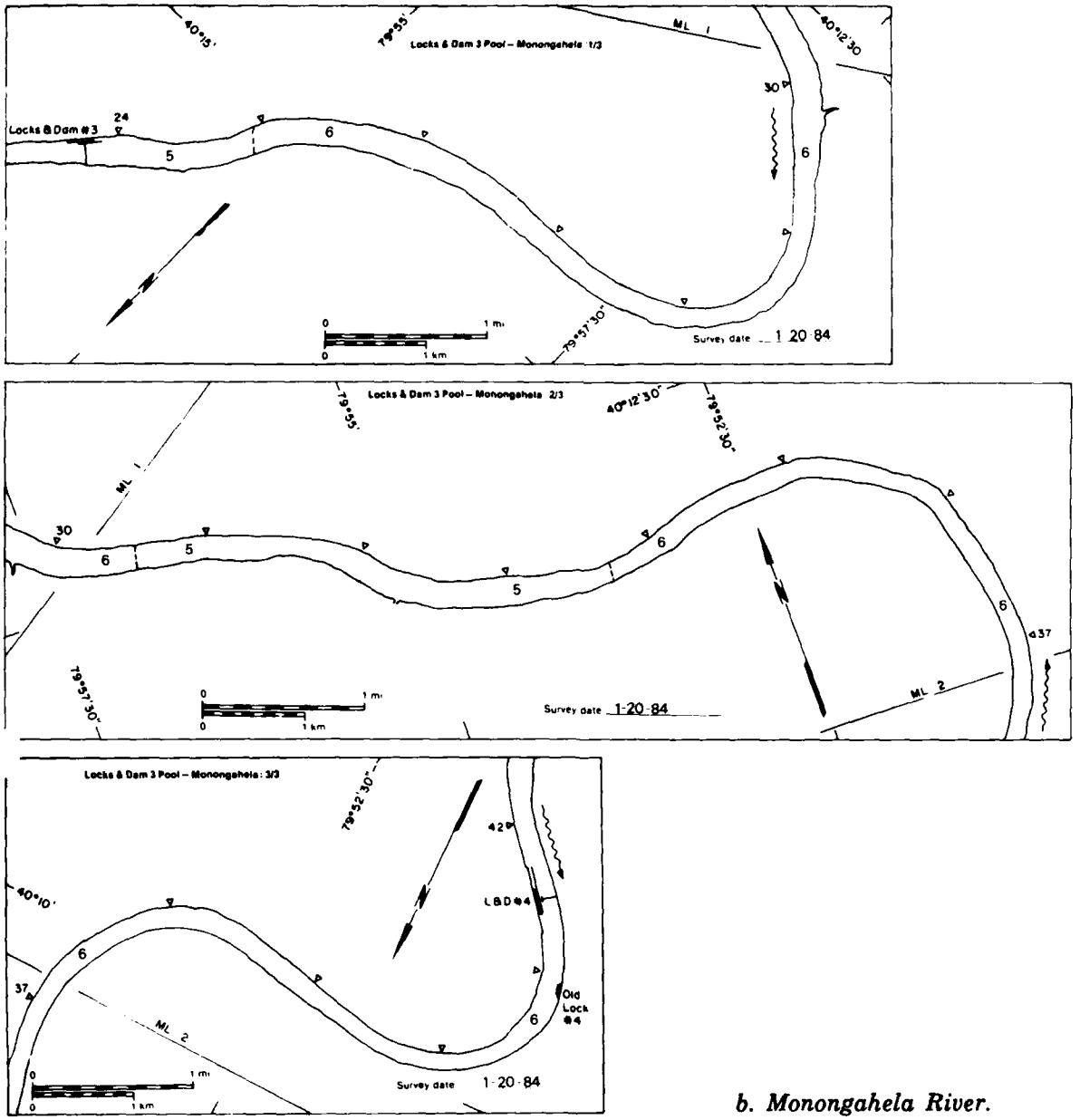


b. Monongahela River.

Figure 6. Maximum extent of ice cover observed on Landsat images.



a. Allegheny River



b. Monongahela River.

Figure 7. Maps prepared from aerial observations and photographs, 20 January 1984 (from Gatto and Daly 1986). See Table 3 for definitions of numbers that indicate ice types.

ice extent on the Monongahela was recorded on videotapes on 4 February when 42% of the river was ice-covered. The last ice observed on the rivers was also recorded on videotapes taken on 24 February. Analysis of the tapes showed that 0.1% of the Allegheny and 0.3% of the Monongahela had ice. Ice distributions from Landsat and videotapes could not be compared this winter because they were not taken at the same time or within a few days of one another.

SUMMARY AND CONCLUSIONS

Air temperatures during the winters when ice was not observed on Landsat images did not remain below freezing sufficiently long to cause a significant amount of ice to form. Discharge during the winters when no ice was apparent was also high during, or had peaks in, December, January and February. Such high discharge would tend to break up ice and flush it downstream, thus prohibiting ice buildup so that it would not become visible on Landsat images.

Ice was observed on the Allegheny River on Landsat images during 10 of the 13 winters from 1972 to 1985 (Fig. 6a). The most severe ice conditions were observed on the Allegheny in 1976–77 when all of the river had some ice cover and 89% of it was covered with white ice. During the remaining 9 winters, ice was observed on all of the river three times but white ice was not as extensive as in 1976–77. Ice was observed on the Monongahela River with Landsat images during 7 winters (Fig. 6b). The maximum extent of ice observed was 100% in 1983–84, 94% in 1976–77 and 45% or less of the river during the remaining 5 winters. Ice conditions on both rivers changed rapidly. This was apparent from Landsat images and aerial observations.

Grey ice, which most likely consisted of floes, pans and slush, or thin, snow-free ice, sometimes with many or large interspersed open areas, was observed most frequently on Landsat images. White ice, which probably consisted of thicker ice or snow-covered ice, sometimes with small or few interspersed open areas, occurred less often.

During the 13 winters from 1972 to 1985, the ice first observed on Landsat images was generally seen in late December or early January and ice last observed was seen in mid- to late-February (Fig. 8, Table 7). The earliest and latest dates when ice was observed on images were 28 December 1980 and 12 March 1984. The ice as observed on images lasted the longest during the 1983–84 winter.

Analysis of Landsat images provides data on general ice conditions, especially during harsh winters when ice is extensive and impedes river navigation. During winters when ice is not extensive and long-lasting, Landsat images may not be as useful. The images provide a view of large reaches of a river on each scene at a reasonable cost. In addition, for many rivers in cold regions, Landsat images may be the only source of data on ice conditions.

Table 7. Dates ice was first and last observed on Landsat images.

1972–73	*1973–74*	*1974–75*	*1975–76*	*1976–77*	*1977–78*	*1978–79*	*1979–80*	*1980–81*	*1981–82*	*1982–83*	*1983–84*	*1984–85*
					Allegheny River							
11 Jan	25 Jan	—	06 Jan	31 Dec	12 Jan	29 Dec	—	28 Dec	—	19 Jan	29 Dec	16 Jan
17 Feb	—	—	23 Jan	22 Feb	31 Jan	16 Jan	—	—	—	—	12 Mar*	24 Feb**
					Monongahela River							
11 Jan	—	—	—	31 Dec	12 Jan	—	—	28 Dec	27 Jan	—	29 Dec	16 Jan
17 Feb	—	—	—	22 Feb	31 Jan	—	—	05 Jan	—	—	12 Mar*	24 Feb**

*Based on aerial and Landsat observations

**Based on videotape and Landsat observations

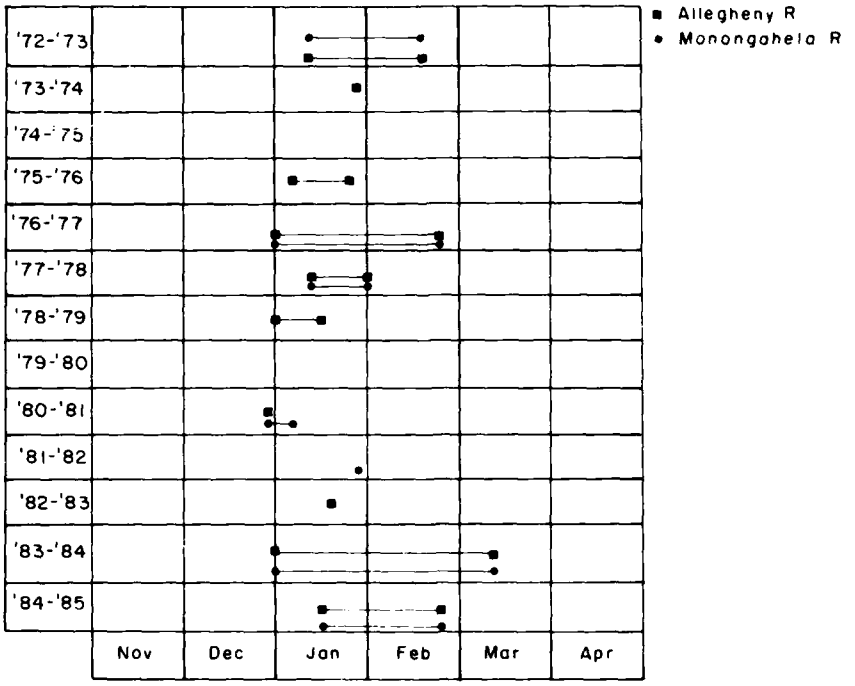


Figure 8. Times of first and last ice as observed on Landsat images and videotapes, and from aerial observations.

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APPENDIX A: LANDSAT IMAGES ANALYZED

River pools to the end of the navigation channel.

Pool no./ length (mi)	Pool start and stop points (river miles)	Approximate surface area* ($ft^2 x 10^6$)
	Allegheny River	
1/9.8	River mile 72 to L&D† 9(62.2)	38.81
2/9.6	L&D 9 to L&D 8 (52.6)	43.09
3/6.9	L&D 8 to L&D 7(45.7)	34.61
4/9.4	L&D 7 to L&D 6(36.3)	47.15
5/5.9	L&D 6 to L&D 5(30.4)	24.92
6/6.2	L&D 5 to L&D 4(24.2)	31.10
7/9.7	L&D 4 to L&D 3(14.5)	56.34
8/7.8	L&D 3 to L&D 2(6.7)	43.22
9/6.7	L&D 2 to Pittsburgh Point(0)	33.05
	Monongahela River	
1/13.3	River mile 128.7 to Opekiska L&D (115.4)	31.60
2/7.4	Opekiska L&D to Hildebrand L&D (108)	17.58
3/6.0	Hildebrand L&D to Morgantown L&D (102)	17.42
4/11.2	Morgantown L&D to L&D 8(90.8)	32.53
5/5.8	L&D 8 to L&D 7(85)	19.91
6/23.8	L&D 7 to Maxwell L&D (61.2)	81.68
7/19.7	Maxwell L&D to L&D 4(41.5)	71.04
8/17.7	L&D 4 to L&D 3(23.8)	71.47
9/12.6	L&D 3 to L&D 2(11.2)	51.34
10/11.2	L&D 2 to Pittsburgh Point (0)	50.91

* When the water level is at normal pool elevation.

†L&D means lock and dam.

Allegheny River

Dates	Allegheny River Pools 1	2	3	4	5	6	7	8	9
1972-73 (6 dates)									
18 Nov	X	X	X	X	X	X	X	X	X
7 Dec				X	X	X	X	X	X
11 Jan	X	X	X	X	X	X	X	X	X
12 Jan				X	X	X	X	X	X
17 Feb	X	X	X	X	X	X	X	X	X
24 Mar	X	X	X	X	X	X	X	X	X
1973-74 (4 dates)									
1 Dec	X	X	X	X	X	X	X	X	X
2 Dec	X	X	X	X	X	X	X	X	X
25 Jan	X	X	X	X	X	X	X	X	X
20 Mar	X	X	X	X	X	X	X	X	X
1974-75 (3 dates)									
27 Nov	X				X	X	X	X	X
2 Jan	X	X			X	X	X	X	X
23 Mar	X	X	X	X	X	X	X	X	X
1975-76 (9 dates)									
6 Jan	X	X	X	X	X	X	X	X	X
23 Jan	X	X	X						
10 Feb				X	X	X	X	X	X
19 Feb	X	X	X	X	X	X	X	X	X
28 Feb	X	X	X	X	X	X	X	X	X
29 Feb				X	X	X	X	X	X
8 Mar	X	X	X	X	X	X	X	X	X
9 Mar	X								
26 Mar	X	X	X	X	X	X	X	X	X
1976-77 (12 dates)									
13 Dec			X	X	X	X	X	X	X
30 Dec	X	X	X	X	X	X	X	X	X
31 Dec	X	X	X	X	X	X	X	X	X
17 Jan	X	X	X	X	X	X	X	X	X
18 Jan	X	X	X	X	X	X	X	X	X
5 Feb				X	X	X	X	X	X
11 Feb	X	X		X	X	X	X	X	X
22 Feb	X	X	X	X	X	X	X	X	X
23 Feb	X	X		X	X	X	X	X	X
12 Mar	X								
13 Mar	X	X							
30 Mar	X	X	X	X	X	X	X	X	X

Dates	Allegheny River Pools 1	2	3	4	5	6	7	8	9
1977-78 (5 dates)									
1 Nov	X								
7 Dec	X	X	X	X	X	X	X	X	X
8 Dec	X	X	X	X	X				
12 Jan	X	X	X	X	X	X	X	X	X
31 Jan			X	X	X	X	X	X	X
1978-79 (4 dates)									
5 Nov	X	X	X	X					
11 Dec	X	X	X	X	X	X	X	X	X
29 Dec	X	X	X	X	X	X	X	X	X
16 Jan	X	X	X	X	X	X	X	X	X
1979-80 (3 dates)									
18 Nov	X	X	X	X	X	X	X	X	X
19 Nov	X	X	X	X	X	X	X	X	X
12 Jan	X	X	X	X	X	X	X	X	X
1980-81 (5 dates)									
22 Nov				X	X	X	X	X	X
30 Nov									X
27 Dec	X	X	X	X	X	X	X	X	X
28 Dec	X	X	X	X	X	X	X	X	X
28 Mar				X	X	X	X	X	X
1981-82 (5 dates)									
25 Nov	X	X	X	X	X	X	X	X	X
10 Jan				X	X	X	X	X	X
27 Jan	X	X	X	X	X	X	X	X	X
28 Jan				X	X	X	X	X	X
1 Apr		X	X	X	X	X	X	X	X
1982-83 (4 dates)									
8 Dec								X	X
18 Dec	X	X	X	X	X	X	X	X	X
19 Jan	X	X	X	X	X	X	X	X	X
27 Feb								X	X
1983-84 (5 dates)									
26 Nov								X	X
22 Jan	X	X	X	X	X	X	X	X	X
10 Mar	X	X	X	X	X	X	X	X	X
12 Mar	X	X	X	X	X	X	X	X	X
2 Apr									X
1984-85 (2 dates)									
7 Jan									X
16 Jan	X	X	X	X	X	X	X	X	X

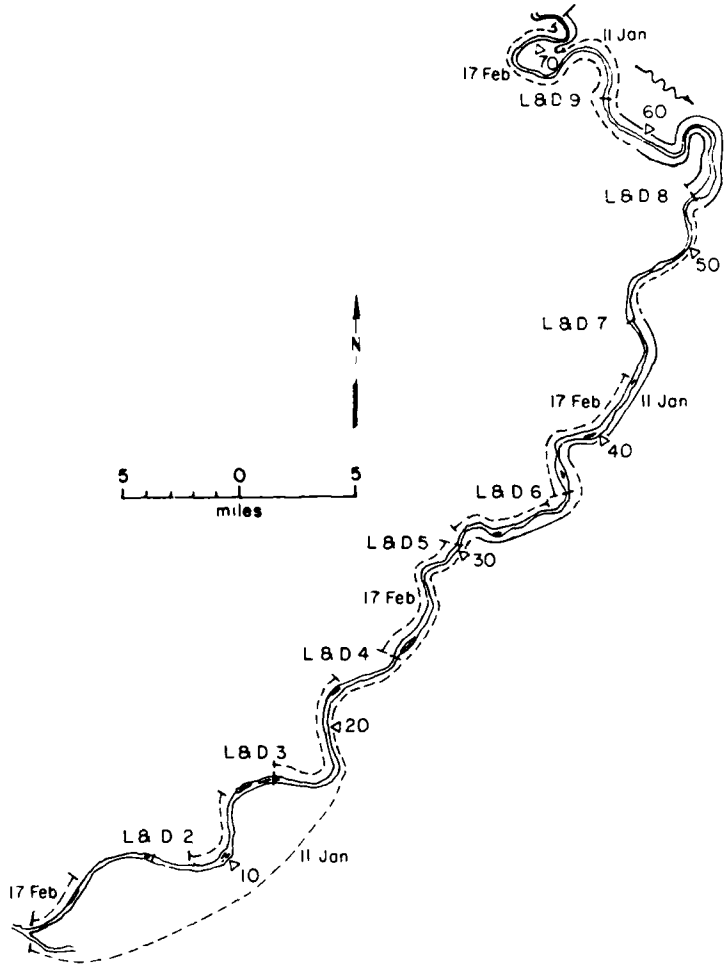
Monongahela River

Dates	Monongahela River Pools									
	1	2	3	4	5	6	7	8	9	10
1972-73 (6 dates)										
18 Nov	X	X	X	X	X	X	X	X	X	X
7 Dec	X	X	X	X	X	X	X	X	X	X
11 Jan	X	X	X	X	X	X	X	X	X	X
12 Jan	X	X	X	X	X	X	X	X	X	X
17 Feb	X	X	X	X	X	X	X	X	X	X
24 Mar			X	X	X	X	X	X	X	X
1973-74 (4 dates)										
1 Dec	X	X	X	X	X	X	X	X	X	X
2 Dec	X	X	X	X	X	X	X	X	X	X
25 Jan	X	X	X	X	X	X	X	X	X	X
20 Mar	X	X	X	X	X	X	X	X	X	X
1974-75 (3 dates)										
27 Nov	X	X	X	X	X	X	X	X	X	X
2 Jan	X	X	X	X	X	X	X	X	X	X
23 Mar		X	X	X	X	X	X	X	X	X
1975-76 (7 dates)										
6 Jan	X	X	X	X	X	X	X	X	X	X
10 Feb	X	X	X	X	X	X	X	X	X	X
19 Feb	X	X	X	X	X	X	X	X	X	X
28 Feb	X	X	X	X	X	X	X	X	X	X
29 Feb	X	X	X	X	X	X	X	X	X	X
8 Mar				X	X	X	X	X	X	X
26 Mar				X	X	X	X	X	X	X
1976-77 (10 dates)										
13 Dec	X	X	X	X	X	X	X	X	X	X
30 Dec				X	X	X	X	X	X	X
31 Dec	X	X	X	X	X	X	X	X	X	X
17 Jan				X	X	X	X	X	X	X
18 Jan	X	X	X	X	X	X	X	X	X	X
5 Feb	X	X	X	X	X	X	X	X	X	X
11 Feb	X	X	X	X	X	X	X	X	X	X
22 Feb	X	X	X	X	X	X	X	X	X	X
23 Feb		X	X	X	X	X	X	X	X	X
30 Mar	X	X	X	X	X	X	X	X	X	X

Dates	Monongahela River Pools									
	1	2	3	4	5	6	7	8	9	10
1977-78 (4 dates)										
20 Nov	X	X				X	X	X	X	
7 Dec						X	X	X	X	X
12 Jan	X	X	X	X	X	X	X	X	X	X
31 Jan	X	X	X	X	X	X	X	X	X	X
1978-79 (3 dates)										
11 Dec	X	X	X	X	X	X	X	X	X	X
29 Dec						X	X	X	X	X
16 Jan	X	X	X	X	X	X	X	X	X	X
1979-80 (3 dates)										
18 Nov	X	X	X	X	X	X	X	X	X	X
19 Nov	X	X	X	X	X	X	X	X	X	X
12 Jan	X	X	X	X	X	X	X	X	X	X
1980-81 (6 dates)										
22 Nov	X	X	X	X	X	X	X	X	X	X
30 Nov			X	X	X	X	X	X	X	X
27 Dec		X	X	X	X	X	X	X	X	X
28 Dec	X	X	X	X	X	X	X	X	X	X
5 Jan	X	X	X	X	X	X	X	X		
28 Mar	X	X	X	X	X	X	X	X	X	X
1981-82 (5 dates)										
25 Nov									X	X
10 Jan	X	X	X	X	X	X	X	X	X	X
27 Jan	X	X	X	X	X	X	X	X	X	X
28 Jan	X	X	X	X	X	X	X	X	X	X
1 Apr	X	X	X	X	X	X	X	X	X	X
1982-83 (4 dates)										
8 Dec				X	X	X	X	X	X	X
18 Dec	X	X	X	X	X	X	X	X	X	X
19 Jan	X	X	X	X	X	X	X	X	X	X
27 Feb										X
1983-84 (5 dates)										
26 Nov										X
22 Jan	X	X	X	X	X	X	X	X	X	X
10 Mar	X	X	X	X	X	X	X	X	X	X
12 Mar	X	X	X	X	X	X	X	X	X	X
2 Apr										X
1984-85 (3 dates)										
7 Jan										X
16 Jan	X	X	X	X	X	X	X	X	X	X
5 Mar	X	X	X							

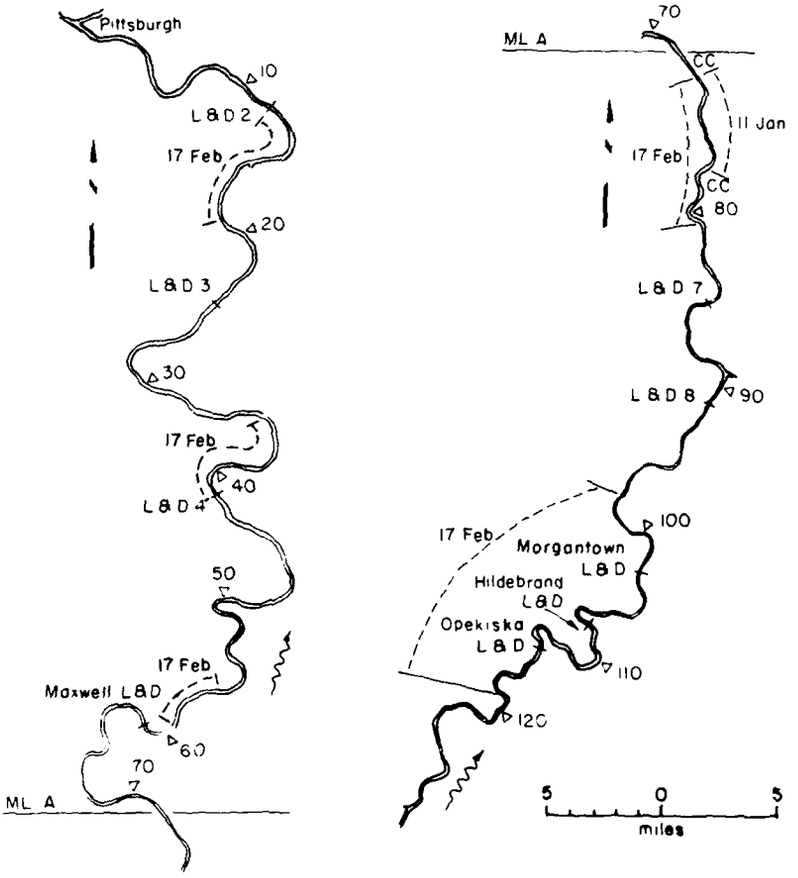
APPENDIX B: ICE DISTRIBUTIONS AS OBSERVED ON LANDSAT IMAGES

Only those reaches of the rivers where Landsat showed ice are presented. Some of the maps have a CC or NOI at the end of the line showing the areal extent of ice on a pool. The CC means the rest of the pool was cloud-covered (e.g., Fig. B1b). The NOI means the rest of the pool was not on the image (e.g., Fig. B4b). On all maps, a dashed line denotes grey ice and a solid line, white ice.



a. Allegheny River.

Figure B1. 1972–73 winter.



b. Monongahela River.

Figure B1 (cont'd). 1972–73 winter.

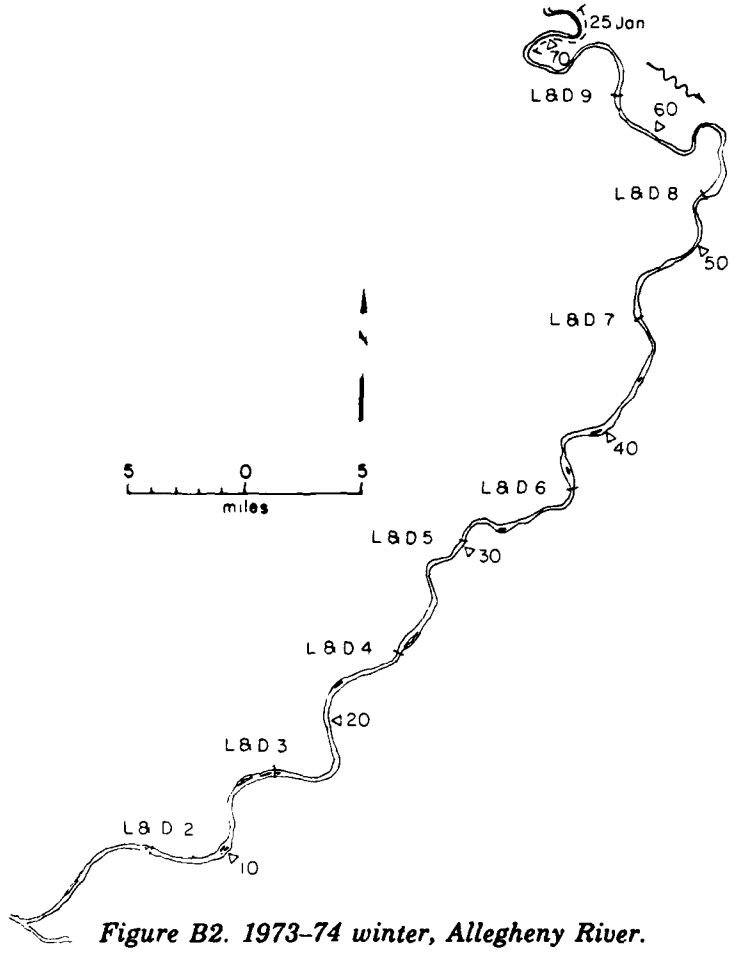


Figure B2. 1973–74 winter, Allegheny River.

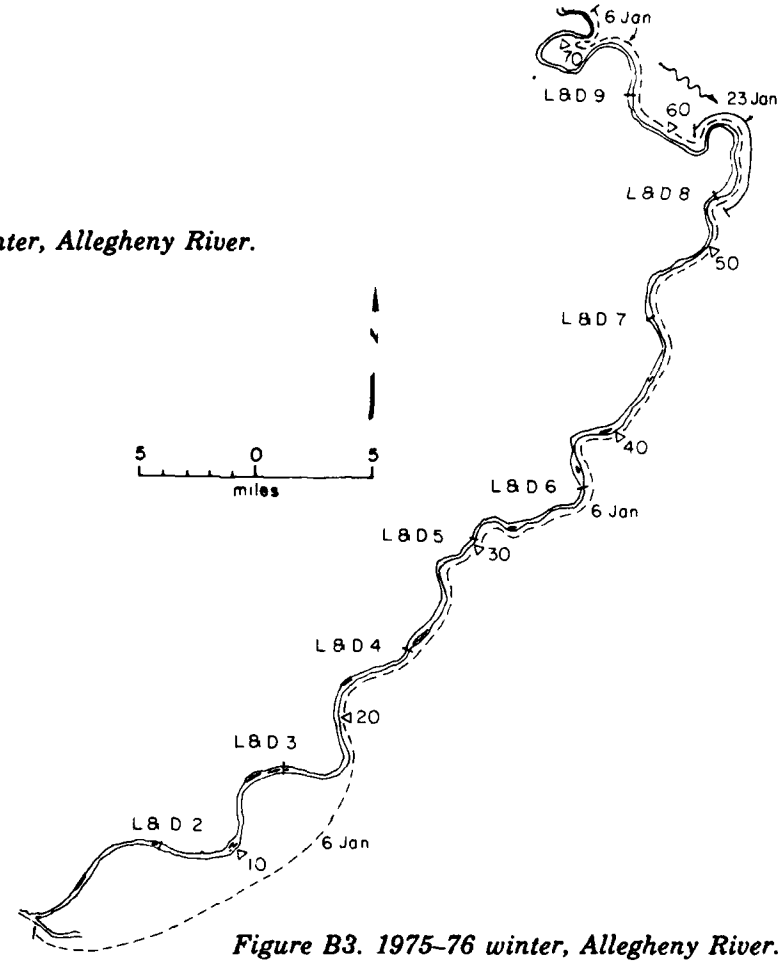
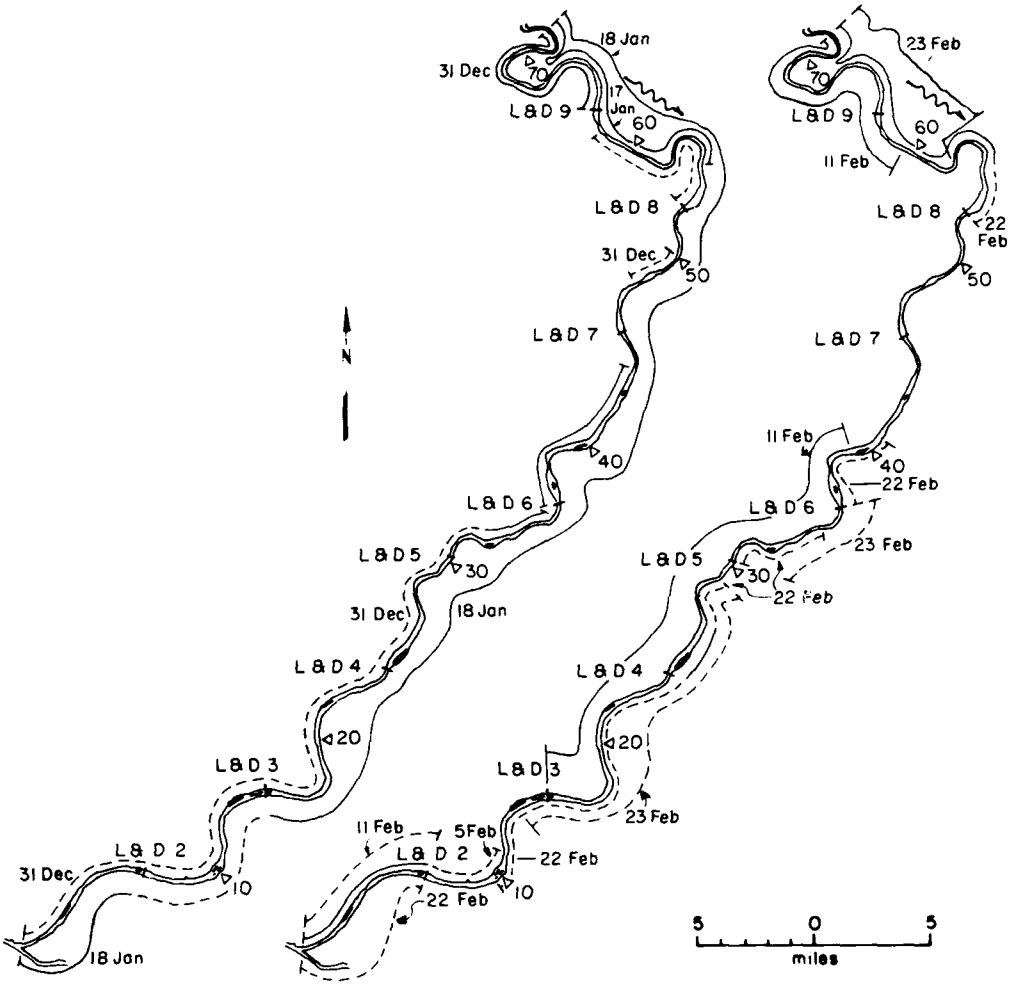


Figure B3. 1975–76 winter, Allegheny River.

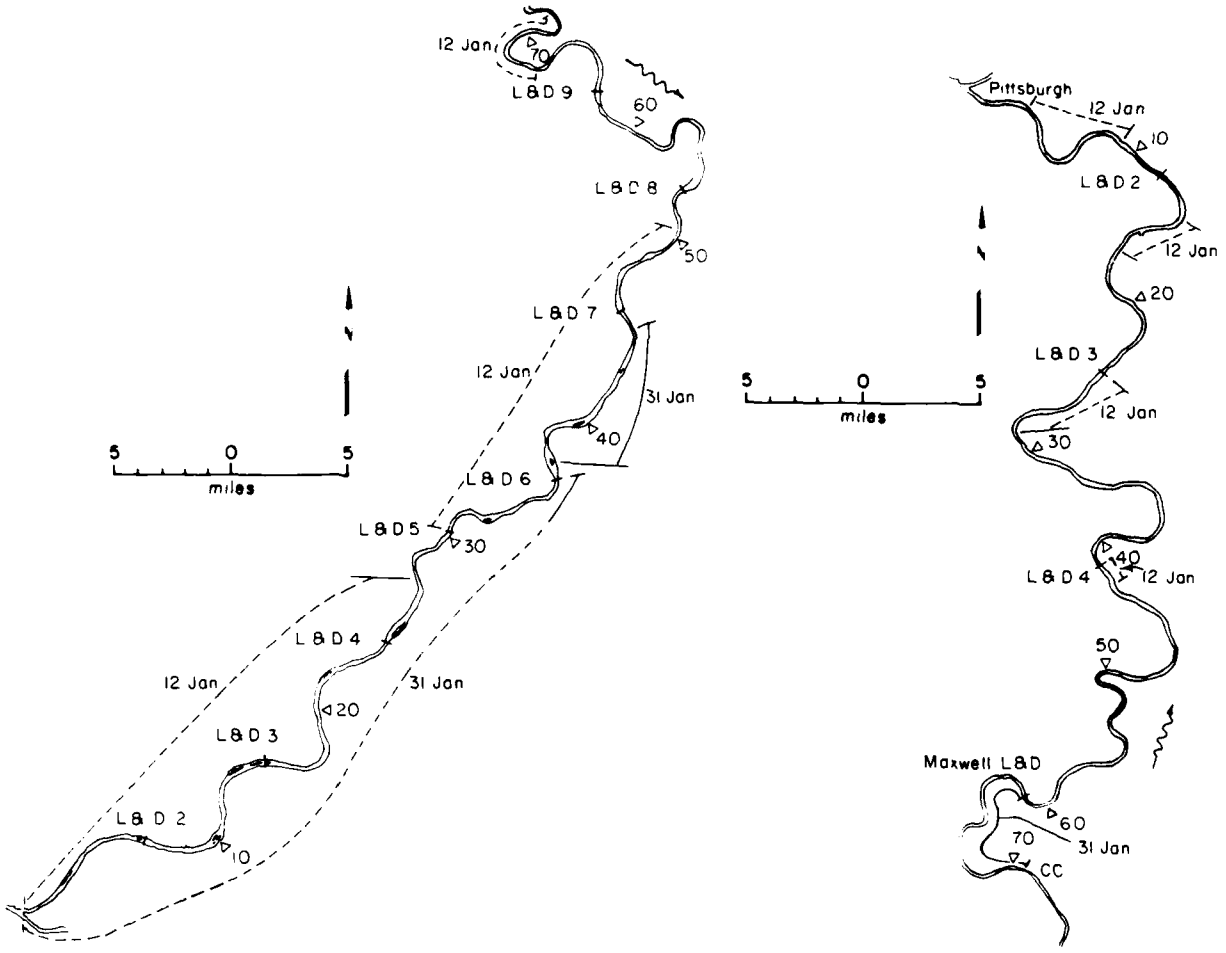


a. Allegheny River.

Figure B4. 1976–77 winter.

b. Monongahela River.

Figure B4 (cont'd).



a. Allegheny River. *b. Monongahela River.*

Figure B5. 1977–78 winter.

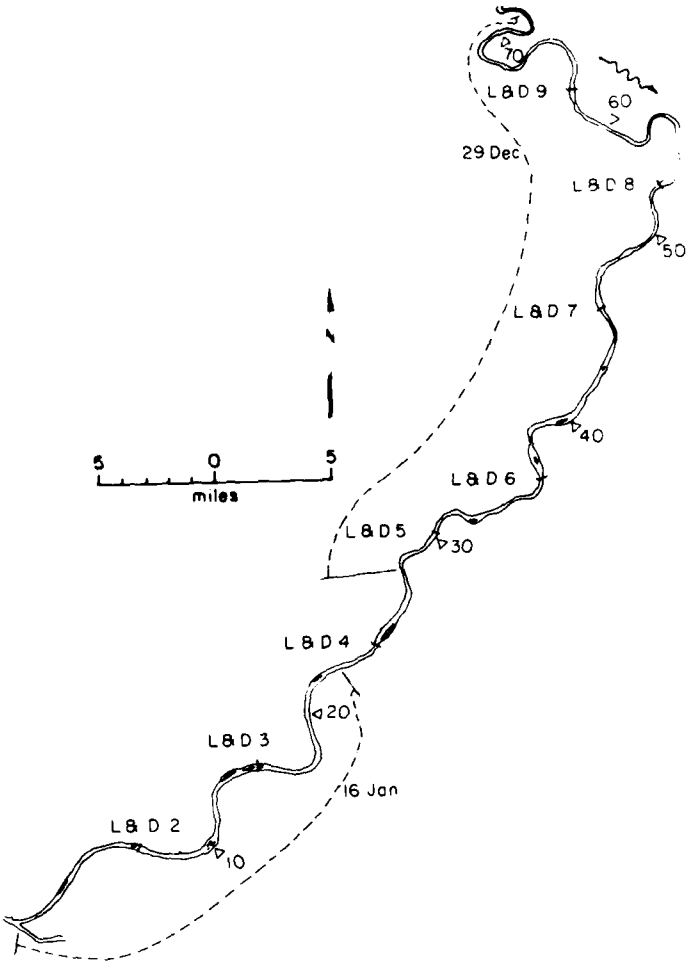
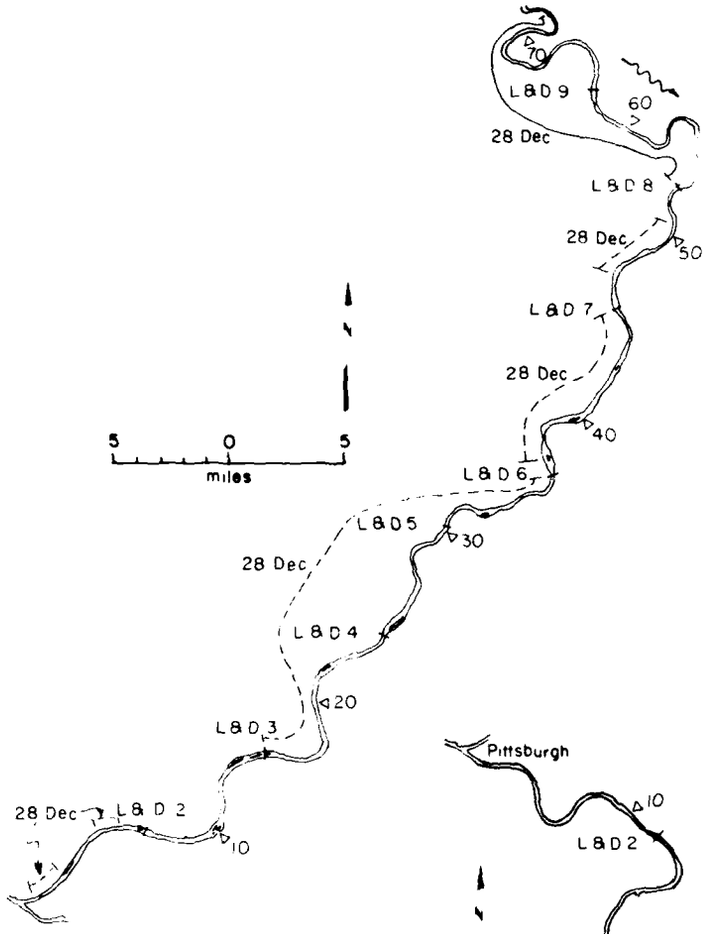
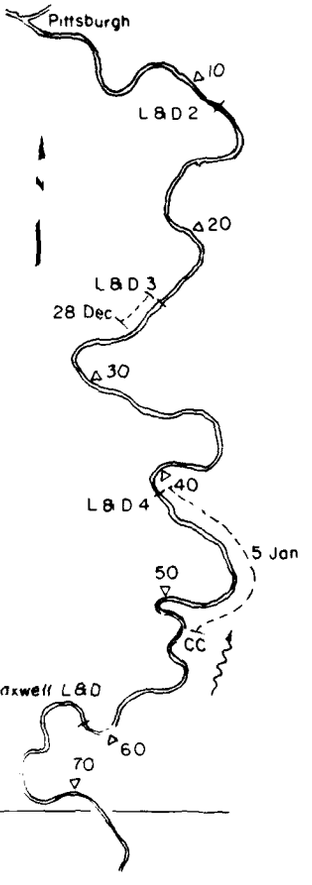
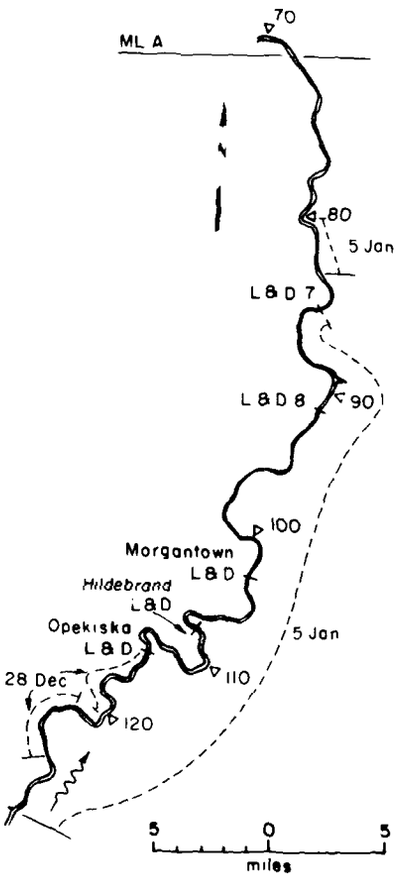


Figure B6. 1978–79 winter, Allegheny River.

a. Allegheny River.







b. Monongahela River.

Figure B7. 1980–81 winter.

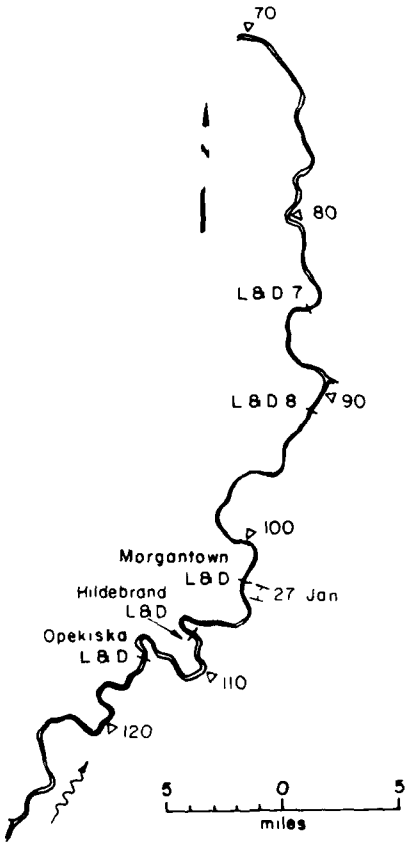


Figure B8. 1981–82 winter, Monongahela River.

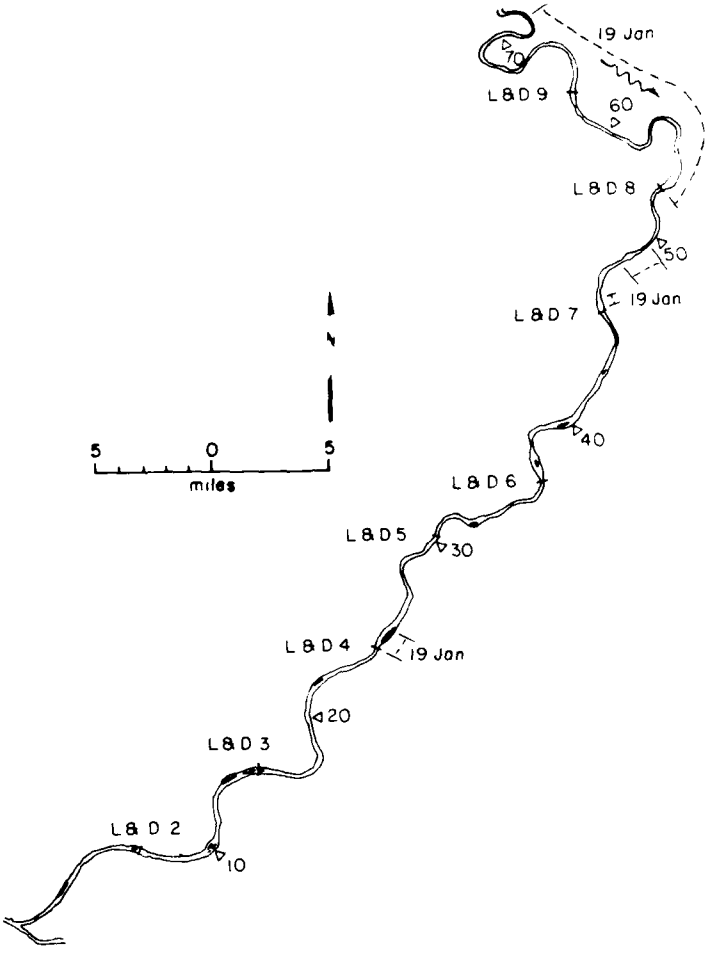


Figure B9. 1982–83 winter, Allegheny River.

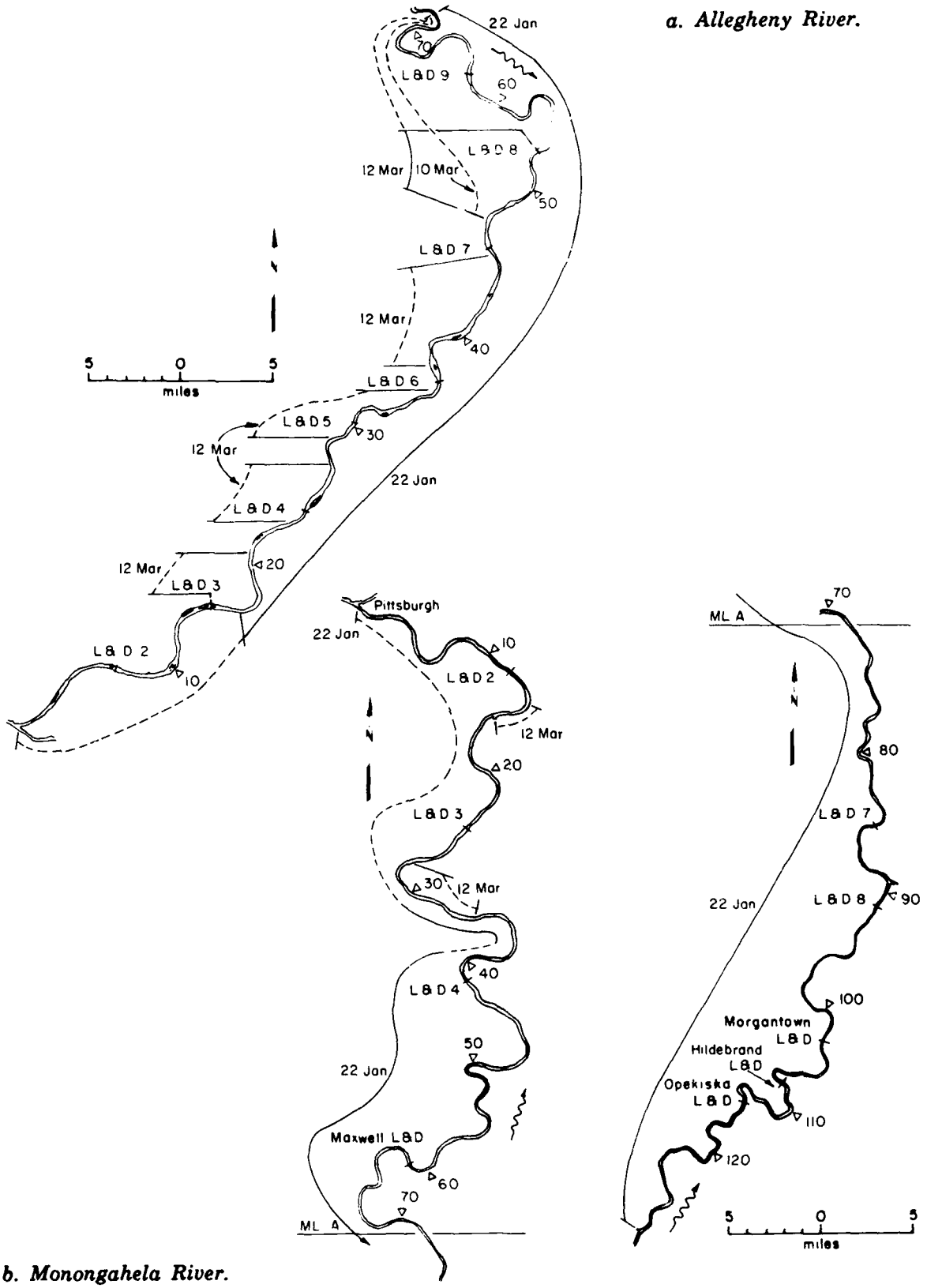
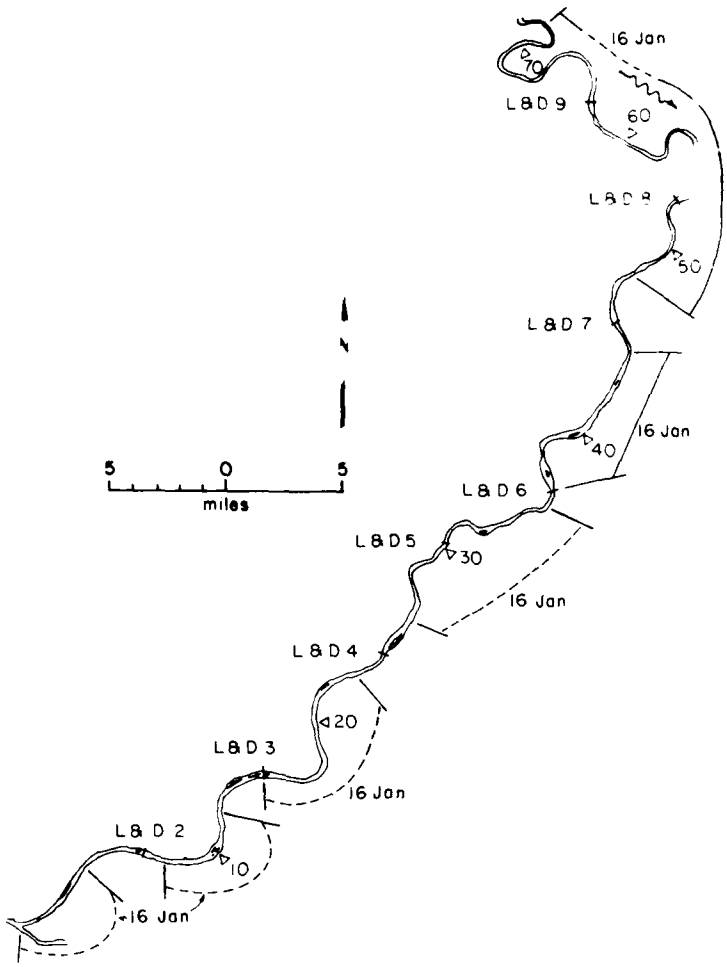
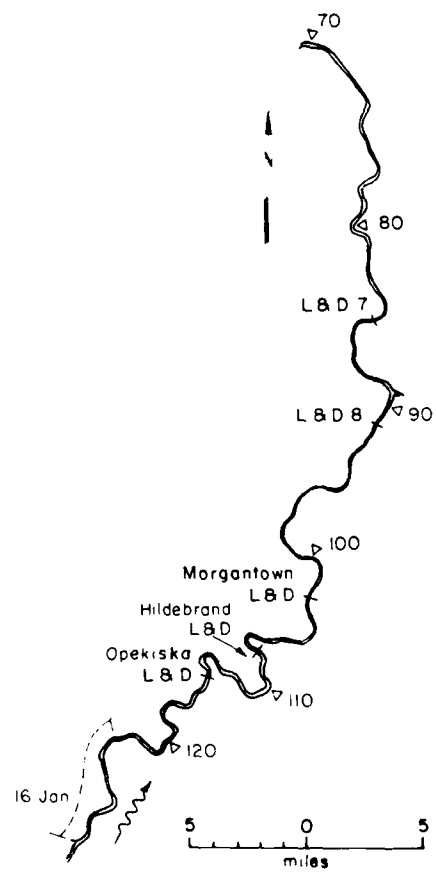


Figure B10. 1983–84 winter.



a. Allegheny River.



b. Monongahela River.

Figure B11. 1984–85 winter.

APPENDIX C: OPEN WATER, GREY ICE AND WHITE ICE

Emsworth Pool begins at Pittsburgh Point in this appendix.

Allegheny River

Pool: L/D 9 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 38.81 (estimated)
Length (mi): 9.8[3]

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1972-73										
18 Nov 72										CC
11 Jan 73				3.3	13.08	33.7	6.5	25.73	66.3	
17 Feb 73				9.8	*	100				
24 Mar 73	9.8	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	9.8	*	100							
25 Jan 74				3	11.88	30.6				6.8 mi-CC
20 Mar 74	9.8	*	100							
1974-75										
27 Nov 74	9.8	*	100							PC
2 Jan 75	9.8	*	100							
23 Mar 75	9.8	*	100							
1975-76										
6 Jan 76				9.8	*	100				
23 Jan 76										CC
19 Feb 76										CC
28 Feb 76										CC
8 Mar 76										CC
9 Mar 76										CC
26 Mar 76	9.8	*	100							
1976-77										
30 Dec 76										CC
31 Dec 76							9.8	*	100	
17 Jan 77							9.8	*	100	
18 Jan 77							9.8	*	100	
11 Feb 77							9.8	*	100	
22 Feb 77							9.8	*	100	
23 Feb 77							9.8	*	100	
12 Mar 77										CC
13 Mar 77	9.8	*	100							
30 Mar 77	9.8	*	100							PC

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1977-78										
1 Nov 77	2	7.29	20.4							7.8 mi-NOI
7 Dec 77										CC
8 Dec 77	9.8	*	100							
12 Jan 78	9.8	18.98	48.9	5	19.79	51.1				
1978-79										
5 Nov 78	9.8	*	100							RBV
11 Dec 78	7.8	30.89	79.6							low, 2 mi-CC
29 Dec 78				9.8	*	100				RBV
16 Jan 79										CC
1979-80										
18 Nov 79	9.8	*	100							RBV
19 Nov 79	9.8	*	100							RBV
12 Jan 80	9.8	*	100							
1980-81										
27 Dec 80										CC
28 Dec 80							9.8	*	100	
1981-82										
25 Nov 81	9.8	*	100							RBV
27 Jan 82										CC
1982-83										
18 Dec 82	9.8	*	100							
19 Jan 83				9.8	*	100				PC; TM
1983-84										
22 Jan 84							9.8	*	100	
10 Mar 84				9.8	*	100				
12 Mar 84				9.8	*	100				TM
1984-85										
16 Jan 85				2.8	11.09	28.6	7	27.72	71.4	PC

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

[3]Only to the end of the navigation channel at river mile 72.

*Area equals entire area of pool.

Pool: L/D 8 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 43.09 (estimated)
Length (mi): 9.6

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
11 Jan 73				0.4	1.81	4.2	9.2	41.28	95.8	
17 Feb 73				2.2	9.87	22.9	7.4	33.22	77.1	
24 Mar 73	9.6	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	9.6	*	100							
25 Jan 74										CC
20 Mar 74	9.6	*	100							
1974-75										
2 Jan 75	2	8.96	20.8							low, 7.6 mi-NOI
23 Mar 75	9.6	*	100							
1975-76										
6 Jan 76				9.6	*	100				
23 Jan 76							5.9	26.50	61.5	3.7 mi-CC
19 Feb 76										CC
28 Feb 76										CC
8 Mar 76										CC
26 Mar 76	9.6	*	100							
1976-77										
30 Dec 76										CC
31 Dec 76	1.2	5.39	12.5	1.2	5.39	12.5	7.2	32.32	75	
17 Jan 77							7.2	32.32	75	2.4 mi-CC
18 Jan 77							9.6	*	100	
11 Feb 77							2	8.96	20.8	7.6 mi-NOI
22 Feb 77				2.4	10.78	25	7.2	32.32	75	
23 Feb 77							4.2	18.87	43.8	5.4 mi-NOI
13 Mar 77	4.8	21.55	50							4.8 mi-NOI
30 Mar 77	9.6	*	100							
1977-78										
7 Dec 77										CC
8 Dec 77	9.6	*	100							
12 Jan 78	9.6	*	100							
1978-79										
5 Nov 78	9.6	*	100							RBV
11 Dec 78										CC
29 Dec 78				9.6	*	100				RBV
16 Jan 79										CC
1979-80										
18 Nov 79	9.6	*	100							RBV
19 Nov 79	9.6	*	100							
12 Jan 80	9.6	*	100							RBV
1980-81										
27 Dec 80										CC
28 Dec 80							9.6	*	100	
1981-82										
25 Nov 81	9.6	*	100							RBV
27 Jan 82										CC
1 Apr 82	9.6	*	100							RBV

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1982-83										
18 Dec 82	9.6	*	100							
19 Jan 83				9.6	*	100				TM
1983-84										
22 Jan 84							9.6	*	100	
10 Mar 84				9.6	*	100				
12 Mar 84				9.6	*	100				TM
1984-85										
16 Jan 85				2.2	9.87	22.9	7.4	35.22	77.1	PC

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 7 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 34.61 (estimated)
Length (mi): 6.9

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
11 Jan 73				6.9	*	100				
17 Feb 73	6.9	*	100							
24 Mar 73	6.9	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	6.9	*	100							
25 Jan 74										CC
20 Mar 74	6.9	*	100							
1974-75										
23 Mar 75	6.9	*	100							
1975-76										
6 Jan 76				6.9	*	100				
23 Jan 76										up. 2 mi-CC; 4.9 mi-NOI
19 Feb 76										CC
28 Feb 76										CC
8 Mar 76										CC
26 Mar 76	6.9	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76										CC
31 Dec 76	4.9	24.57	71.0	2	10.04	29.0				
17 Jan 77										CC
18 Jan 77							6.9	*	100	
22 Feb 77	6.9	*	100							
30 Mar 77	6	30.08	86.9							low. .9 mi-CC
1977-78										
7 Dec 77	2.9	15.54	42.0							up. 4 mi-CC
8 Dec 77	6.9	*	100							
12 Jan 78	2.4	12.04	34.8	4.5	22.57	65.2				
31 Jan 78	1.5	7.51	21.7							up. 5.4 mi-NOI; PC
1978-79										
5 Nov 78	6.9	*	100							RBV
11 Dec 78										CC
29 Dec 78				6.9	*	100				RBV
16 Jan 79										CC
1979-80										
18 Nov 79	6.9	*	100							RBV
19 Nov 79	6.9	*	100							
12 Jan 80	6.9	*	100							RBV
1980-81										
27 Dec 80										CC
28 Dec 80	3.8	19.07	55.1	3.1	15.54	44.9				
1981-82										
25 Nov 81	6.9	*	100							RBV
27 Jan 82										CC
1 Apr 82	6.9	*	100							RBV

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1982-83										
18 Dec 82	6.9	*	100							
19 Jan 83	5.4	27.10	78.3	1.5	7.51	21.7				TM
1983-84										
22 Jan 84							6.9	*	100	
10 Mar 84	1.8	9.03	26.1	5.1	25.58	73.9				
12 Mar 84	1.8	9.03	26.1				5.1	25.58	73.9	TM
1984-85										
16 Jan 85	2.8	14.04	40.6				4.1	20.57	59.4	PC

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 6 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 47.15 (estimated)
Length (mi): 9.4

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72	7.4	37.11	78.7							up. 2 mi-NOI
11 Jan 73				0.7	3.49	7.4	8.7	43.66	92.6	
12 Jan 73										up. 2 mi-NOI; low. 7.4 mi-CC
17 Feb 73	2.7	13.53	28.7	6.7	33.62	71.3				
24 Mar 73	9.4	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	9.4	*	100							
25 Jan 74										CC
20 Mar 74	9.4	*	100							
1974-75										
23 Mar 75	9.4	*	100							
1975-76										
6 Jan 76				9.4	*	100				
10 Feb 76										up. 4.4 mi-NOI; low. 5 mi-CC
19 Feb 76	6	30.08	63.8							up. 3.4 mi-PC
28 Feb 76										CC
29 Feb 76	8	40.12	85.1							up. 1.4 mi-NOI
8 Mar 76										CC
26 Mar 76	9.4	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76										CC
31 Dec 76	1.7	8.53	18.1				7.7	38.62	81.9	
17 Jan 77										CC
18 Jan 77							9.4	*	100	
5 Feb 77										3 mi-CC; 6.4 mi-NOI
11 Feb 77							3.2	16.03	34.0	6.2 mi-NOI
22 Feb 77	5	25.08	53.2	4.4	22.07	46.8				
23 Feb 77	4.7	23.58	50							4.7 mi-NOI
30 Mar 77										CC
1977-78										
7 Dec 77	9.4	*	100							
8 Dec 77	1	5.00	10.6							low. 8.4 mi-CC
12 Jan 78				9.4	*	100				
31 Jan 78	1.2	6.04	12.8				8.2	41.11	87.2	PC
1978-79										
5 Nov 78	4.7	23.58	50							low. 4.7 mi-NOI; RBV
11 Dec 78										CC
29 Dec 78				9.4	*	100				RBV
16 Jan 79										CC
1979-80										
18 Nov 79	9.4	*	100							RBV
19 Nov 79	9.4	*	100							
12 Jan 80	9.4	*	100							RBV

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1980-81										
22 Nov 80	7.9	39.61	84.0							up. 1.5 mi-NOI
27 Dec 80										CC
28 Dec 80	.5	2.50	5.3	8.9	44.65	94.7				
28 Mar 81	7.9	39.61	84.0							up. 1.5 mi-NOI
1981-82										
25 Nov 81	9.4	*	100							RBV
10 Jan 82										low. 8.4 mi-CC; up. 1 mi-NOI
27 Jan 82										CC
28 Jan 82										low. 5.4 mi-CC; up. 4 mi-NOI
1 Apr 82	9.4	*	100							RBV
1982-83										
18 Dec 82	9.4	*	100							
19 Jan 83	9.4	*	100							TM
1983-84										
22 Jan 84							9.4	*	100	
10 Mar 84	9.4	*	100							
12 Mar 84	1.2	6.04	12.8	8.2	41.11	87.2				TM
1984-85										
16 Jan 85	1.5	7.52	16.0				7.9	39.63	84.0	PC

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 5 River: Alleghany
Surface Area ($ft^2 \times 10^6$)[1]: 24.92 (estimated)
Length (mi): 5.9

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72	5.9	*	100							
11 Jan 73				1.8	7.60	30.5	4.1	17.32	69.5	
12 Jan 73										CC
17 Feb 73	1.3	5.48	22	4.6	19.44	78				
24 Mar 73	5.9	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	5.9	*	100							
25 Jan 74										CC
20 Mar 74	5.9	*	100							
1974-75										
27 Nov 74	3	12.66	50.8							up. 2.9 mi-NOI
2 Jan 75	3	12.66	50.8							up. 2.9 mi-NOI
23 Mar 75	5.9	*	100							
1975-76										
6 Jan 76				5.9	*	100				
10 Feb 76										CC
19 Feb 76	5.9	*	100							
28 Feb 76										CC
29 Feb 76	5.9	*	100							
8 Mar 76										CC
26 Mar 76	5.9	*	100							
1976-77										
13 Dec 76	4	16.90	67.8							low. 1.9 mi-CC
30 Dec 76										CC
31 Dec 76	.8	3.39	13.6	1.6	6.75	27.1	3.5	14.78	59.3	
17 Jan 77										CC
18 Jan 77							5.9	*	100	
5 Feb 77										CC
11 Feb 77							5.9	*	100	
22 Feb 77	1.3	5.48	22	4.6	19.44	78				
23 Feb 77				5.9	*	100				
30 Mar 77										CC
1977-78										
7 Dec 77	5.9	*	100							
8 Dec 77										up. 4.4 mi-CC; low. 1.5 mi-NOI
12 Jan 78				5.9	*	100				
31 Jan 78				4.6	19.44	78	1.3	5.48	22.2	PC
1978-79										
11 Dec 78										CC
29 Dec 78				5.9	*	100				RBV
16 Jan 79										CC
1979-80										
18 Nov 79	5.9	*	100							RBV
19 Nov 79	5.9	*	100							
12 Jan 80	5.9	*	100							RBV
1980-81										
22 Nov 80	5.9	*	100							
27 Dec 80										CC
28 Dec 80				5.9	*	100				
28 Mar 81	5.9	*	100							

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1981-82										
25 Nov 81	5.9	*	100							RBV
10 Jan 82										CC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	5.9	*	100							RBV
1982-83										
18 Dec 82	5.9	*	100							
19 Jan 83	5.9	*	100							TM
1983-84										
22 Jan 84							5.9	*	100	
10 Mar 84	5.9	*	100							
12 Mar 84	0.8	3.39	13.6	5.1	21.53	86.4				TM
1984-85										
16 Jan 85	0.8	3.38	13.6	5.1	21.54	86.4				

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 4 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 31.10 (estimated)
Length (mi): 6.2

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72	6.2	*	100							
11 Jan 73				6.2	*	100				
12 Jan 73										CC
17 Feb 73				6.2	*	100				
24 Mar 73	6.2	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	6.2	*	100							
25 Jan 74										CC
20 Mar 74	6.2	*	100							
1974-75										
27 Nov 74	6.2	*	100							
2 Jan 75	6.2	*	100							
23 Mar 75	6.2	*	100							
1975-76										
6 Jan 76				6.2	*	100				
10 Feb 76										CC
19 Feb 76	6.2	*	100							
28 Feb 76										CC
29 Feb 76	6.2	*	100							
8 Mar 76										CC
26 Mar 76	6.2	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76										CC
31 Dec 76				6.2	*	100				
17 Jan 77										CC
18 Jan 77							6.2	*	100	
5 Feb 77										CC
11 Feb 77							6.2	*	100	
22 Feb 77	.9	4.51	14.5	2.8	14.06	45.2	2.5	12.53	40.3	
23 Feb 77	.9	4.51	14.5	5.3	26.59	85.5				
30 Mar 77										CC
1977-78										
7 Dec 77	6.2	*	100							
12 Jan 78	3	15.05	48.4	3.2	16.05	51.6				
31 Jan 78				6.2	*	100				PC
1978-79										
11 Dec 78	2.2	11.04	35.5							up. 4 mi-CC
29 Dec 78	3.8	19.06	61.3	2.4	12.04	38.7				RBV
16 Jan 79										CC
1979-80										
18 Nov 79	6.2	*	100							RBV
19 Nov 79	6.2	*	100							
12 Jan 80	6.2	*	100							RBV
1980-81										
22 Nov 80	6.2	*	100							
27 Dec 80										CC
28 Dec 80				6.2	*	100				
28 Mar 81	6.2	*	100							

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1981-82										
25 Nov 81	3	15.05	48.4							low. 3.2 mi-CC; RBV
10 Jan 82										CC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	6.2	*	100							RBV
1982-83										
18 Dec 82	6.2	*	100							
19 Jan 83	5.4	27.09	87.1	.8	4.01	12.9				TM
1983-84										
22 Jan 84							6.2	*	100	NT
10 Mar 84	6.2	*	100							
12 Mar 84	2	10.03	32.3	4.2	21.07	67.7				TM
1984-85										
16 Jan 85	2	10.03	32.3	4.2	21.07	67.7				

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visib ..

*Area equals entire area of pool.

Pool: L/D 3 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 56.34 (estimated)
Length (mi): 9.7

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72	4	23.21	41.2							low, 5.3 mi-CC
11 Jan 73				9.7	*	100				
12 Jan 73										CC
17 Feb 73	2.7	15.66	27.8	7	40.68	72.2				
24 Mar 73	9.7	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	9.7	*	100							
25 Jan 74	9.7	*	100							
20 Mar 74	9.7	*	100							
1974-75										
27 Nov 74	8	46.48	82.5							low, 1.7 mi-CC
2 Jan 75	9.7	*	100							
23 Mar 75										CC
1975-76										
6 Jan 76				9.7	*	100				
10 Feb 76										CC
19 Feb 76	9.7	*	100							
28 Feb 76										CC
29 Feb 76	9.7	*	100							
8 Mar 76										CC
26 Mar 76	9.7	*	100							
1976-77										
13 Dec 76	9.7	*	100							
30 Dec 76										CC
31 Dec 76				9.7	*	100				
17 Jan 77										CC
18 Jan 77							9.7	*	100	
5 Feb 77										CC
11 Feb 77							9.7	*	100	
22 Feb 77				9.7	*	100				
23 Feb 77				9.7	*	100				
30 Mar 77										CC
1977-78										
7 Dec 77	1	5.80	10.3							low, 8.7 mi-CC
12 Jan 78				9.7	*	100				
31 Jan 78				9.7	*	100				PC
1978-79										
11 Dec 78	9.7	*	100							
29 Dec 78	9.7	*	100							RBV
16 Jan 79				7.9	45.86	81.4				up, 1.8 mi-CC
1979-80										
18 Nov 79	9.7	*	100							RBV
19 Nov 79	9.7	*	100							
12 Jan 80	9.7	*	100							RBV
1980-81										
22 Nov 80	9.7	*	100							
27 Dec 80										CC
28 Dec 80				9.7	*	100				
28 Mar 81	9.7	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
25 Nov 81										CC;RBV
10 Jan 82										CC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	9.7	*	100							RBV
1982-83										
18 Dec 82	9.7	*	100							
19 Dec 82	7.7	44.73	79.4							low. 2 mi-CC;TM
1983-84										
22 Jan 84				1.9	11.04	19.6	7.8	45.30	80.4	NT in white ice
10 Mar 84	9.7	*	100							
12 Mar 84	3	17.41	30.9	6.7	38.93	69.1				TM
1984-85										
16 Jan 85	1.6	9.29	16.5	8.1	47.05	83.5				

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 2 River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 43.22 (measured)
Length (mi): 7.8

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72										CC
11 Jan 73				7.8	*	100				
12 Jan 73										CC
17 Feb 73	3.3	18.28	42.3	4.5	24.94	57.7				
24 Mar 73	7.8	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	7.8	*	100							
25 Jan 74	7.8	*	100							
20 Mar 74	7.8	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75	7.8	*	100							
23 Mar 75										CC
1975-76										
6 Jan 76				7.8	*	100				
10 Feb 76										CC
19 Feb 76	7.8	*	100							
28 Feb 76										CC
29 Feb 76	7.8	*	100							
8 Mar 76										CC
26 Mar 76	7.8	*	100							
1976-77										
13 Dec 76	3	16.64	38.5							low, 4.8 mi-CC
30 Dec 76										CC
31 Dec 76				7.8	*	100				
17 Jan 77										CC
18 Jan 77				7.8	*	100				
5 Feb 77	3.7	20.49	47.4	4.1	22.73	52.6				
11 Feb 77	7.8	*	100							
22 Feb 77	3.2	17.72	41.0	4.6	25.50	59				
23 Feb 77				1.4	7.74	17.9				6.4 mi-CC
30 Mar 77										CC
1977-78										
7 Dec 77										CC
12 Jan 78				7.8	*	100				
31 Jan 78				7.8	*	100				PC
1978-79										
11 Dec 78	7.8	*	100							
29 Dec 78	7.8	*	100							RBV
16 Jan 79				7.8	*	100				
1979-80										
18 Nov 79	7.8	*	100							RBV
19 Nov 79	7.8	*	100							
12 Jan 80	7.8	*	100							RBV
1980-81										
22 Nov 80	7.8	*	100							
27 Dec 80										CC
28 Dec 80	7.8	*	100							
28 Mar 81	7.8	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
25 Nov 81	7.3	40.45	93.6							up. .5 mi-CC;RBV
10 Jan 82	7.8	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	7.8	*	100							RBV
1982-83										
8 Dec 82	3	16.64	38.5							up. 4.8 mi-NOI: RBV
18 Dec 82	7.8	*	100							PC
19 Jan 83	5.8	32.16	74.4							up. 2 mi-CC;TM
27 Feb 83	2.5	13.87	32.1							up. 5.3 mi-NOI
1983-84										
26 Nov 83	2.5	13.87	32.1							up. 5.3 mi-NOI
22 Jan 84				7.8	*	100				
10 Mar 84	7.8	*	100							
12 Mar 84	7.8	*	100							TM
1984-85										
16 Jan 85	3.6	19.96	46.2	4.2	23.25	53.8				

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: Emsworth River: Allegheny
Surface Area ($ft^2 \times 10^6$)[1]: 33.05 (measured)
Length (mi): 6.7

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72										CC
11 Jan 73				6.7	*	100				
12 Jan 73										CC
17 Feb 73	3.5	17.25	52.2	3.2	15.80	47.8				
24 Mar 73	6.7	*	100							
1973-74										
1 Dec 73	5.5	24.66	74.6							up. 1.7 mi-CC
2 Dec 73	6.7	*	100							
25 Jan 74	6.7	*	100							
20 Mar 74	6.7	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75										CC
1975-76										
6 Jan 76				6.7	*	100				
10 Feb 76										CC
19 Feb 76	6.7	*	100							
28 Feb 76										CC
29 Feb 76	6.7	*	100							
8 Mar 76										CC
26 Mar 76	6.7	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76										CC
31 Dec 76				6.7	*	100				
17 Jan 77										CC
18 Jan 77							6.7	*	100	
5 Feb 77							6.7	*	100	
11 Feb 77				6.7	*	100				
22 Feb 77				6.7	*	100				
23 Feb 77										CC
30 Mar 77										CC
1977-78										
7 Dec 77	5.2	25.65	77.6							up. 1.5 mi-CC
12 Jan 78				6.7	*	100				
31 Jan 78				6.7	*	100				PC
1978-79										
11 Dec 78										CC
29 Dec 78	6.7	*	100							RBV
16 Jan 79				6.7	*	100				
1979-80										
18 Nov 79	6.7	*	100							RBV
19 Nov 79	6.7	*	100							
12 Jan 80	6.7	*	100							RBV
1980-81										
22 Nov 80	6.7	*	100							
30 Nov 80	4.7	23.17	70.1							up. 2 mi-NOI;RBV
27 Dec 80										CC
28 Dec 80	4	19.73	59.7	2.7	13.32	40.3				
28 Mar 81	6.7	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
25 Nov 81	6.7	*	100							RBV
10 Jan 82	6.7	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	6.7	*	100							RBV
1982-83										
8 Dec 82	6.7	*	100							RBV
18 Dec 82	6.7	*	100							PC
19 Jan 83	1.5	7.40	22.4							up. 5.2 mi-CC;TM
27 Feb 83	6.7	*	100							
1983-84										
26 Nov 83	6.7	*	100							
22 Jan 84				6.7	*	100				
10 Mar 84	6.7	*	100							
12 Mar 84	6.7	*	100							TM
2 Apr 84	5.7	28.13	85.1							up. 1 mi-NOI
1984-85										
7 Jan 85										CC
16 Jan 85	3	14.81	44.8	3.7	18.24	55.2				

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Monongahela River

Pool: Opekiska River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 31.60 (estimated)
Length (mi): 13.3[3]

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	9.3	22.09	69.9							up. 4 mi-NOI
7 Dec 72	13.3	*	100							
11 Jan 73										low. 12.3 mi-CC; up. 1 mi-NOI
12 Jan 73										CC
17 Feb 73	9.8	23.29	73.7	3.5	8.31	26.3				
1973-74										
1 Dec 73										low. 9.3 mi-CC; up. 4 mi-NOI
2 Dec 73	13.3	*	100							
25 Jan 74										CC
20 Mar 74	13.3	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
1975-76										
6 Jan 76	13.3	*	100							
10 Feb 76	13.3	*	100							
19 Feb 76	1.2	2.84	9							up. 12.1 mi-NOI
28 Feb 76	13.3	*	100							
29 Feb 76	13.3	*	100							
1976-77										
13 Dec 76										CC
31 Dec 76				13.3	*	100				
18 Jan 77							13.3	*	100	
5 Feb 77										CC
11 Feb 77							13.3	*	100	
22 Feb 77	4.2	9.99	31.6				8.1	19.24	60.9	1 mi-NOI
30 Mar 77										low. 4 mi-CC; up. 9.3 mi-NOI
1977-78										
20 Nov 77	13.3	*	100							
12 Jan 78										low. 4.1 mi-CC; up. 9.2 mi-NOI
31 Jan 78	2.8	6.67	21.1							low. 10.5 mi-CC

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 x 10^6$)	Percent	Length (mi)	Area ($ft^2 x 10^6$)	Percent	Length (mi)	Area ($ft^2 x 10^6$)	Percent	Remarks[2]
1978-79										
11 Dec 78	12	28.50	90.2							up. 1.3 mi-NOI
16 Jan 79										CC
1979-80										
18 Nov 79	1.2	2.84	9							up. 12.1 mi-NOI
19 Nov 79	13.3	*	100							
12 Jan 80	13.3	*	100							
1980-81										
22 Nov 80	13.3	*	100							
28 Dec 80	5.5	13.08	41.4	7.8	18.52	58.6				
5 Jan 81				13.3	*	100				RBV
28 Mar 81	13.3	*	100							
1981-82										
10 Jan 82	13.3	*	100							PC
27 Jan 82	1	2.37	7.5							up. 12.3 mi-NOI
28 Jan 82										CC
1 Apr 82	13.3	*	100							RBV
1982-83										
18 Dec 82	13.3	*	100							RBV
19 Jan 83										CC; TM
1983-84										
22 Jan 84							13.3	*	100	
10 Mar 84	13.3	*	100							
12 Mar 84	13.3	*	100							TM
1984-85										
16 Jan 85	7.2	17.11	54.1	6.1	14.49	45.9				
5 Mar 85	13.3	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

[3]Only to river mile 128.7 at the confluence of the Tygart Valley and West Fork Rivers.

*Area equals entire area of pool.

Pool: Hildebrand River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 17.58 (estimated)
Length (mi): 7.4

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	7.4	*	100							
7 Dec 72	7.4	*	100							
11 Jan 73										CC
12 Jan 73										CC
17 Feb 73				7.4	*	100				
1973-74										
1 Dec 73										CC
2 Dec 73	7.4	*	100							
25 Jan 74										CC
20 Mar 74	7.4	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75	1.2	2.85	16.2							up. 6.2 mi-NOI
1975-76										
6 Jan 76	7.4	*	100							
10 Feb 76	7.4	*	100							
19 Feb 76	7.4	*	100							
28 Feb 76	7.4	*	100							
29 Feb 76	7.4	*	100							
1976-77										
13 Dec 76										CC
31 Dec 76	4.4	10.46	59.5	3	7.12	40.5				
18 Jan 77				4.4	10.46	59.5	3	7.12	40.5	
5 Feb 77										CC
11 Feb 77	3.9	9.26	52.7				3.5	8.32	47.3	
22 Feb 77	7.4	*	100							
23 Feb 77	7.4	*	100							
30 Mar 77										CC
1977-78										
20 Nov 77	2.5	5.94	33.8							low. 4.9 mi-NOI
12 Jan 78										CC
31 Jan 78										CC
1978-79										
11 Dec 78	7.4	*	100							
16 Jan 79										CC
1979-80										
18 Nov 79	7.4	*	100							
19 Nov 79	7.4	*	100							
12 Jan 80	7.4	*	100							
1980-81										
22 Nov 80	7.4	*	100							
27 Dec 80										CC
28 Dec 80	7.4	*	100							
5 Jan 81				7.4	*	100				RBV
28 Mar 81	7.4	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
10 Jan 82	7.4	*	100							PC
27 Jan 82	7.4	*	100							
28 Jan 82										CC
1 Apr 82	7.4	*	100							RBV
1982-83										
18 Dec 82	7.4	*	100							
19 Jan 83										CC; TM
1983-84										
22 Jan 84							7.4	*	100	
10 Mar 84	7.4	*	100							
12 Mar 84	7.4	*	100							TM
1984-85										
16 Jan 85	7.4	*	100							
5 Mar 85	7.4	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: Morgantown River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 17.42 (estimated)
Length (mi): 6

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	6	*	100							
7 Dec 72	6	*	100							
11 Jan 73										CC
12 Jan 73										CC
17 Feb 73				6	*	100				
24 Mar 73	5.4	15.68	90							up. .6 mi-NOI
1973-74										
1 Dec 73										CC
2 Dec 73	6	*	100							
25 Jan 74	4	11.62	66.7							up. 2 mi-CC
20 Mar 74	6	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75	6	*	100							
1975-76										
6 Jan 76	6	*	100							
10 Feb 76	2.2	6.39	36.7							low. 3.8 mi-CC
19 Feb 76	6	*	100							
28 Feb 76	6	*	100							
29 Feb 76	6	*	100							
1976-77										
13 Dec 76										CC
31 Dec 76				6	*	100				
18 Jan 77							6	*	100	
5 Feb 77										CC
11 Feb 77	1.9	5.52	31.7				1.3	3.78	21.7	low. 2.8 mi-NOI
22 Feb 77	6	*	100							
23 Feb 77	6	*	100							
30 Mar 77										CC
1977-78										
12 Jan 78										CC
31 Jan 78										CC
1978-79										
11 Dec 78	6	*	100							
16 Jan 79										CC
1979-80										
18 Nov 79	6	*	100							
19 Nov 79	6	*	100							
12 Jan 80	6	*	100							
1980-81										
22 Nov 80	6	*	100							
30 Nov 80	5.5	15.97	91.7							up. .5 mi-NOI
27 Dec 80										CC
28 Dec 80	6	*	100							
5 Jan 81				6	*	100				RBV
28 Mar 81	6	*	100							

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1981-82										
10 Jan 82	6	*	100							PC
27 Jan 82	5.1	14.81	85	.9	2.61	15				
28 Jan 82										CC
1 Apr 82	6	*	100							RBV
1982-83										
18 Dec 82	6	*	100							
19 Jan 83										CC;TM
1983-84										
22 Jan 84							6	*	100	
10 Mar 84	6	*	100							
12 Mar 84	6	*	100							TM
1984-85										
16 Jan 85	6	*	100							
5 Mar 85	6	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 8 River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 32.53 (estimated)
Length (mi): 11.2

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1972-73										
18 Nov 72	11.2	*	100							
7 Dec 72	11.2	*	100							
11 Jan 73										CC
12 Jan 73										CC
17 Feb 73	6.7	19.45	59.8	4.5	13.08	40.2				
24 Mar 73	11.2	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	11.2	*	100							
25 Jan 74	11.2	*	100							
20 Mar 74	11.2	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75	11.2	*	100							
1975-76										
6 Jan 76	11.2	*	100							
10 Feb 76										CC
19 Feb 76	11.2	*	100							
28 Feb 76	11.2	*	100							
29 Feb 76	11.2	*	100							
8 Mar 76	9.8	28.46	87.5							up. 1.4 mi-NOI
26 Mar 76	5.5	15.97	49.1							up. 5.7 mi-NOI
1976-77										
13 Dec 76										CC
30 Dec 76	2.8	8.13	25							mid. 4.8 mi-CC; up. 3.6 mi-NOI
31 Dec 76	4.7	13.66	42	6.5	18.87	58				
17 Jan 77							7.7	22.38	68.8	up. 3.5 mi-NOI
18 Jan 77							11.2	*	100	
5 Feb 77										CC
11 Feb 77	1.1	3.19	9.8	2.8	8.13	25	1.1	3.19	9.8	6.2 mi-NOI
22 Feb 77	11.2	*	100							
23 Feb 77	9.7	28.17	86.6							low. 1.5 mi-NOI
30 Mar 77										CC
1977-78										
12 Jan 78										CC
31 Jan 78										CC
1978-79										
11 Dec 78	11.2	*	100							
16 Jan 79										CC
1979-80										
18 Nov 79	11.2	*	100							
19 Nov 79	11.2	*	100							
12 Jan 80	11.2	*	100							
1980-81										
22 Nov 80	11.2	*	100							
30 Nov 80	11.2	*	100							
27 Dec 80										CC
28 Dec 80	11.2	*	100							
5 Jan 81				11.2	*	100				RBV
28 Mar 81	11.2	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
10 Jan 82	11.2	*	100							PC
27 Jan 82	11.2	*	100							
28 Jan 82										CC
1 Apr 82	6.2	18.02	55.4							low, 5 mi-CC
1982-83										
8 Dec 82	7.2	20.92	64.3							up, 4 mi-NOI;RBV
18 Dec 82	11.2	*	100							
19 Jan 83										CC;TM
1983-84										
22 Jan 84							11.2	*	100	
10 Mar 84	11.2	*	100							
12 Mar 84	11.2	*	100							TM
1984-85										
16 Jan 85	11.2	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 7 River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 19.91 (estimated)
Length (mi): 5.8

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	5.8	*	100							
7 Dec 72	5.8	*	100							
11 Jan 73										CC
12 Jan 73										CC
17 Feb 73	5.8	*	100							
24 Mar 73	5.8	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	5.8	*	100							
25 Jan 74	5.8	*	100							
20 Mar 74	5.8	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75	3.8	13.04	65.5							low. 2 mi-CC
1975-76										
6 Jan 76	5.8	*	100							
10 Feb 76										CC
19 Feb 76	5.8	*	100							
28 Feb 76	5.8	*	100							
29 Feb 76	5.8	*	100							
8 Mar 76	5.8	*	100							
26 Mar 76	5.8	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76	5.8	*	100							
31 Dec 76	5.8	*	100							
17 Jan 77							5.8	*	100	
18 Jan 77							5.8	*	100	
5 Feb 77										CC
11 Feb 77				2.9	9.96	50				2.9 mi-NOI
22 Feb 77	5.8	*	100							
23 Feb 77	3.4	11.67	58.6							up. 2.4 mi-NOI
30 Mar 77										CC
1977-78										
12 Jan 78										CC
31 Jan 78										CC
1978-79										
11 Dec 78	5.8	*	100							
16 Jan 79										CC
1979-80										
18 Nov 79	5.8	*	100							
19 Nov 79	5.8	*	100							
12 Jan 80	5.8	*	100							
1980-81										
22 Nov 80	5.8	*	100							
30 Nov 80	5.8	*	100							
27 Dec 80										CC
28 Dec 80	5.8	*	100							
5 Jan 81				5.8	*	100				RBV
28 Mar 81	5.8	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
10 Jan 82	5.8	*	100							PC
27 Jan 82	4.2	14.41	72.4							low, 1.6 mi-CC
28 Jan 82										CC
1 Apr 82										CC
1982-83										
8 Dec 82	5.8	*	100							RBV
18 Dec 82	5.8	*	100							
19 Jan 83										CC;TM
1983-84										
22 Jan 84							5.8	*	100	
10 Mar 84	5.8	*	100							
12 Mar 84	5.8	*	100							TM
1984-85										
16 Jan 85	5.8	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: Maxwell River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 81.68 (estimated)
Length (mi): 23.8

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	23.8	*	100							
7 Dec 72	23.8	*	100							
11 Jan 73				4.1	14.05	17.2				19.7 mi-CC
12 Jan 73										CC
17 Feb 73	15.8	54.24	66.4	8	27.44	33.6				
24 Mar 73	23.8	*	100							
1973-74										
1 Dec 73										CC
2 Dec 73	23.8	*	100							
25 Jan 74	23.8	*	100							
20 Mar 74	23.8	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75										CC
1975-76										
6 Jan 76	23.8	*	100							
10 Feb 76										low. 5.5 mi-PC; up. 18.3 mi-CC
19 Feb 76	23.8	*	100							
28 Feb 76	23.8	*	100							
29 Feb 76	23.8	*	100							
8 Mar 76	23.8	*	100							
26 Mar 76	23.8	*	100							
1976-77										
13 Dec 76	18.8	64.53	79							low. 5 mi-CC
30 Dec 76	23.8	*	100							
31 Dec 76	23.8	*	100							
17 Jan 77	9.2	31.61	38.7	7.2	24.75	30.3	7.4	25.40	31.1	
18 Jan 77	5.2	17.81	21.8	11.6	39.78	48.7	7	24.01	29.4	
5 Feb 77										CC
11 Feb 77	12.9	44.27	54.2	10.9	37.41	45.8				
22 Feb 77	23.8	*	100							
23 Feb 77	23.8	*	100							
30 Mar 77										CC
1977-78										
20 Nov 77	17.5	60.03	73.5							up. 6.3 mi-NOI
7 Dec 77										low. 11.6 mi-CC; up. 12.2 mi-NOI
12 Jan 78										CC
31 Jan 78							9.5	32.59	39.9	14.3 mi-CC
1978-79										
11 Dec 78	23.8	*	100							
29 Dec 78	3.2	10.95	13.4							up. 20.6 mi-NOI; RBV
16 Jan 79	7	24.01	29.4							up. 16.8 mi-CC
1979-80										
18 Nov 79	23.8	*	100							
19 Nov 79	23.8	*	100							
12 Jan 80	23.8	*	100							

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1980-81										
22 Nov 80	23.8	*	100							
30 Nov 80	23.8	*	100							
27 Dec 80										CC
28 Dec 80	23.8	*	100							
5 Jan 81	6	20.58	25.2	2.8	9.64	11.8				low. 15 mi-CC;RBV
28 Mar 81	23.8	*	100							
1981-82										
10 Jan 82	23.8	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82										CC
1982-83										
8 Dec 82	23.8	*	100							RBV
18 Dec 82	23.8	*	100							
19 Jan 83	19.6	67.30	82.4							up. 4.2 mi-CC;TM
1983-84										
22 Jan 84							23.8	*	100	
10 Mar 84	23.8	*	100							
12 Mar 84	23.8	*	100							TM
1984-85										
16 Jan 85	23.8	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 4 River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 71.04 (measured)
Length (mi): 19.7

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	19.7	*	100							
7 Dec 72	19.7	*	100							
11 Jan 73										CC
12 Jan 73										CC
17 Feb 73	16.8	60.60	85.3	2.9	10.44	14.7				
24 Mar 73	19.7	*	100							
1973-74										
1 Dec 73	5.3	19.11	26.9							up. 14.4 mi-CC
2 Dec 73	19.7	*	100							
25 Jan 74	19.7	*	100							
20 Mar 74	19.7	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75										CC
1975-76										
6 Jan 76	19.7	*	100							
10 Feb 76										CC
19 Feb 76	19.7	*	100							
28 Feb 76	19.7	*	100							
29 Feb 76	19.7	*	100							
8 Mar 76	17.5	63.08	88.8							low. 2.2 mi-CC
26 Mar 76	19.7	*	100							
1976-77										
13 Dec 76	12.2	43.97	61.9							low. 7.5 mi-CC
30 Dec 76	19.7	*	100							
31 Dec 76	19.7	*	100							
17 Jan 77				1.7	6.11	8.6	18	64.93	91.4	NT
18 Jan 77	2	7.25	10.2	2	7.25	10.2	15.7	56.62	79.7	
5 Feb 77										CC
11 Feb 77	2.2	7.96	11.2				17.5	63.08	88.8	
22 Feb 77	14.6	52.64	74.1	5.1	18.40	25.9				
23 Feb 77	19.7	*	100							
30 Mar 77										CC
1977-78										
20 Nov 77	19.7	*	100							CC
7 Dec 77										up. 3.5 mi-CC
12 Jan 78	15.2	54.84	77.2	1	3.61	5.1				low. 15.5 mi-CC
31 Jan 78	4.2	15.13	21.3							
1978-79										
11 Dec 78	19.7	*	100							RBV
29 Dec 78	19.7	*	100							
16 Jan 79	19.7	*	100							
1979-80										
18 Nov 79	19.7	*	100							
19 Nov 79	19.7	*	100							
12 Jan 80	19.7	*	100							
1980-81										
22 Nov 80	19.7	*	100							
30 Nov 80	19.7	*	100							CC
27 Dec 80										
28 Dec 80	19.7	*	100							
5 Jan 81				9	32.47	45.7				up. 10.7 mi-CC; RBV
28 Mar 81	19.7	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1981-82										
10 Jan 82	19.7	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	5.4	19.46	27.4							*up.* 14.3 mi-CC
1982-83										
8 Dec 82	19.7	*	100							RBV
18 Dec 82	19.7	*	100							
19 Jan 83	19.7	*	100							TM
1983-84										
22 Jan 84							19.7	*	100	
10 Mar 84	19.7	*	100							
12 Mar 84	19.7	*	100							TM
1984-85										
16 Jan 85	19.7	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 3 River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 71.47 (measured)
Length (mi): 17.7

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72	17.7	*	100							
7 Dec 72	17.7	*	100							
11 Jan 73	4.5	18.16	25.4							13.2 mi-CC
12 Jan 73										CC
17 Feb 73	12	48.46	67.8	5.7	23.01	32.2				
24 Mar 73	17.7	*	100							
1973-74										
1 Dec 73	17.7	*	100							
2 Dec 73	17.7	*	100							
25 Jan 74	17.7	*	100							
20 Mar 74	17.7	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75										CC
1975-76										
6 Jan 76	17.7	*	100							
10 Feb 76										up. 14.2 mi-PC; low. 3.5 mi-CC
19 Feb 76	17.7	*	100							
28 Feb 76										CC
29 Feb 76	17.7	*	100							
8 Mar 76										CC
26 Mar 76	17.7	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76	17.7	*	100							
31 Dec 76	12.1	48.89	68.4	5.6	22.58	31.6				
17 Jan 77				9.2	37.16	52	8.5	34.31	48	NT
18 Jan 77				9.2	37.16	52	8.5	34.31	48	
5 Feb 77										CC
11 Feb 77	2.3	9.29	13	9.7	39.17	54.8	5.7	23.01	32.2	
22 Feb 77	15.5	62.61	87.6	2.2	8.86	12.4				
23 Feb 77	9.7	39.17	54.8							up. 8 mi-CC
30 Mar 77										CC
1977-78										
20 Nov 77	17.7	*	100							
7 Dec 77										CC
12 Jan 78	12.5	50.46	70.6	5.2	21.01	29.4				
31 Jan 78	3.2	12.94	18.1							up. & low. 14.5 mi-CC
1978-79										
11 Dec 78	17.7	*	100							
29 Dec 78	17.7	*	100							RBW
16 Jan 79	17.7	*	100							
1979-80										
18 Nov 79	17.7	*	100							
19 Nov 79	17.7	*	100							
12 Jan 80	17.7	*	100							

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1980-81										
22 Nov 80	17.7	*	100							
30 Nov 80	17.7	*	100							
27 Dec 80										CC
28 Dec 80	15.5	62.61	87.6	2.2	8.86	12.4				
5 Jan 81	13.9	56.10	78.5							low, 3.8 mi-NOI; RBV
28 Mar 81	17.7	*	100							
1981-82										
10 Jan 82	17.7	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	17.7	*	100							
1982-83										
8 Dec 82	17.7	*	100							RBV
18 Dec 82	17.7	*	100							
19 Jan 83	17.7	*	100							TM
1983-84										
22 Jan 84				9.7	39.16	54.8	8	32.30	45.2	
10 Mar 84	17.7	*	100							
12 Mar 84	11.2	45.24	63.3	6.5	26.23	36.7				TM
1984-85										
16 Jan 85	17.7	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: L/D 2 River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 51.34 (measured)
Length (mi): 12.6

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72	12.6	*	100							
11 Jan 73	2.5	10.17	19.8							10.1 mi-CC
12 Jan 73										CC
17 Feb 73	6.1	24.85	48.4	6.5	29.57	51.6				
24 Mar 73	12.6	*	100							
1973-74										
1 Dec 73	12.6	*	100							
2 Dec 73	12.6	*	100							
25 Jan 74	12.6	*	100							
20 Mar 74	12.6	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75										CC
1975-76										
6 Jan 76	12.6	*	100							
10 Feb 76										CC
19 Feb 76	7.8	31.78	61.9							low. 4.8 mi-CC
28 Feb 76										CC
29 Feb 76	12.6	*	100							
8 Mar 76										CC
26 Mar 76	12.6	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76	12.6	*	100							
31 Dec 76	10	40.76	79.4	2.6	10.58	20.6				
17 Jan 77				12.6	*	100				
18 Jan 77				12.6	*	100				
5 Feb 77										CC
11 Feb 77				12.6	*	100				
22 Feb 77				12.6	*	100				
23 Feb 77										CC
30 Mar 77										CC
1977-78										
20 Nov 77	6	24.44	47.6							low. 6.6 mi-NOI
7 Dec 77										CC
12 Jan 78	8.9	36.25	70.6	3.7	15.09	29.4				
31 Jan 78										CC
1978-79										
11 Dec 78	12.6	*	100							
29 Dec 78	12.6	*	100							RBW
16 Jan 79	12.6	*	100							
1979-80										
18 Nov 79	12.6	*	100							
19 Nov 79	12.6	*	100							
12 Jan 80	12.6	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1980-81										
22 Nov 80	12.6	*	100							
30 Nov 80	12.6	*	100							
27 Dec 80										CC
28 Dec 80	12.6	*	100							
28 Mar 81	12.6	*	100							
1981-82										
25 Nov 81										low. 4.3 mi-CC; up. 8.3 mi-NOI; RBV
10 Jan 82	12.6	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	12.6	*	100							
1982-83										
8 Dec 82	12.6	*	100							RBV
10 Dec 82	12.6	*	100							
19 Jan 83										CC;TM
1983-84										
22 Jan 84				12.6	*	100				
10 Mar 84	12.6	*	100							
12 Mar 84	10.8	44.00	85.7	1.8	7.34	14.3				TM
1984-85										
16 Jan 85	12.6	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

Pool: Emsworth River: Monongahela
Surface Area ($ft^2 \times 10^6$)[1]: 50.91 (measured)
Length (mi): 11.2

Date	OPEN Length (mi)	OPEN Area ($ft^2 \times 10^6$)	OPEN Percent	GREY ICE Length (mi)	GREY ICE Area ($ft^2 \times 10^6$)	GREY ICE Percent	WHITE ICE Length (mi)	WHITE ICE Area ($ft^2 \times 10^6$)	WHITE ICE Percent	Remarks[2]
1972-73										
18 Nov 72										CC
7 Dec 72	11.2	*	100							
11 Jan 73	8.3	37.72	74.1							2.9 mi-CC
12 Jan 73										CC
17 Feb 73	11.2	*	100							
24 Mar 73	11.2	*	100							
1973-74										
1 Dec 73	11.2	*	100							
2 Dec 73	11.2	*	100							
25 Jan 74	11.2	*	100							
20 Mar 74	11.2	*	100							
1974-75										
27 Nov 74										CC
2 Jan 75										CC
23 Mar 75										CC
1975-76										
6 Jan 76	11.2	*	100							
10 Feb 76										CC
19 Feb 76	6.7	30.44	59.8							up. 4.5 mi-CC
28 Feb 76										CC
29 Feb 76	11.2	*	100							
8 Mar 76										CC
26 Mar 76	11.2	*	100							
1976-77										
13 Dec 76										CC
30 Dec 76	11.2	*	100							
31 Dec 76	4.7	21.38	42	6.5	29.53	58				
17 Jan 77				11.2	*	100				
18 Jan 77				11.2	*	100				
5 Feb 77										CC
11 Feb 77	8.8	40.02	78.6	2.4	10.89	21.4				
22 Feb 77				11.2	*	100				
23 Feb 77										CC
30 Mar 77										CC
1977-78										
7 Dec 77										CC
12 Jan 78	5.4	24.54	48.2	5.8	26.37	51.8				
31 Jan 78	10.2	46.38	91.1							up. 1 mi-CC
1978-79										
11 Dec 78	3.2	14.56	28.6							low. 8 mi-CC
29 Dec 78	11.2	*	100							RSV
16 Jan 79	11.2	*	100							
1979-80										
18 Nov 79	11.2	*	100							
19 Nov 79	11.2	*	100							
12 Jan 80	11.2	*	100							

	OPEN			GREY ICE			WHITE ICE			
Date	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Length (mi)	Area ($ft^2 \times 10^6$)	Percent	Remarks[2]
1980-81										
22 Nov 80	11.2	*	100							
30 Nov 80	11.2	*	100							
27 Dec 80										CC
28 Dec 80	11.2	*	100							
28 Mar 81	11.2	*	100							
1981-82										
25 Nov 81	3.5	15.94	31.3							up. 7.7 mi-CC;RBV
10 Jan 82	11.2	*	100							PC
27 Jan 82										CC
28 Jan 82										CC
1 Apr 82	11.2	*	100							
1982-83										
8 Dec 82	11.2	*	100							RBV
18 Dec 82	11.2	*	100							
19 Jan 83										CC;TM
27 Feb 83	8.7	39.56	77.7							up. 2.5 mi-NOI
1983-84										
26 Nov 83	8.7	39.56	77.7							up. 2.5 mi-NOI
22 Jan 84				11.2	*	100				
10 Mar 84	11.2	*	100							
12 Mar 84	11.2	*	100							TM
2 Apr 84	1.5	6.82	13.4							up. 9.7 mi-NOI
1984-85										
7 Jan 85										CC
16 Jan 85	11.2	*	100							

[1]Surface areas of some pools were measured on Corps of Engineers navigation charts (1:24000) with a Los Angeles Scientific Instruments Co. digital compensating polar planimeter. Those areas not measured were estimated by measuring the width of the river every mile on the Corps charts, calculating an average width per pool, then multiplying the average width by the pool length to get the area.

[2]Numbers in miles; CC, cloud-covered; PC, partly cloudy; NOI, not on image; TM, Thematic Mapper; RBV, Return Beam Vidicon; NT, navigation track visible.

*Area equals entire area of pool.

APPENDIX D: DATES AND EXTENT OF ICE FIRST OBSERVED, MAXIMUM EXTENT OF ICE OBSERVED AND ICE LAST OBSERVED ON EACH POOL WITH LANDSAT IMAGES

The bar graphs show the dates during each winter when ice was first observed on each pool (first bar), when it was observed at its maximum extent (middle bar), when it was last observed (last bar), the general type of ice observed on each date, and the percentage of each pool covered by ice on each date (e.g., pool 4, Fig. D4a).

On some of the bar graphs there may not be a bar for each of the first, maximum and last ice observations (e.g., pool 1, Fig. D1a). On pool 1, during the 1972–73 winter, ice was first observed on a Landsat image on 11 January 1973. The ice was grey and white and covered 100% of the pool. The maximum extent of ice as seen on images was observed on 11 January and 17 February 1973 and covered 100% of the pool. It turns out that the ice last observed on Landsat images was also the 17 February 1973 observation. The next usable image was taken on 24 March 1973 and no ice was apparent.

On pool 3 the only ice apparent on a Landsat image was seen on 11 January 1973. The ice was grey and covered 100% of the pool. Since this was the only observation with Landsat that showed ice, there is only one bar on the graph (Fig. D1a).

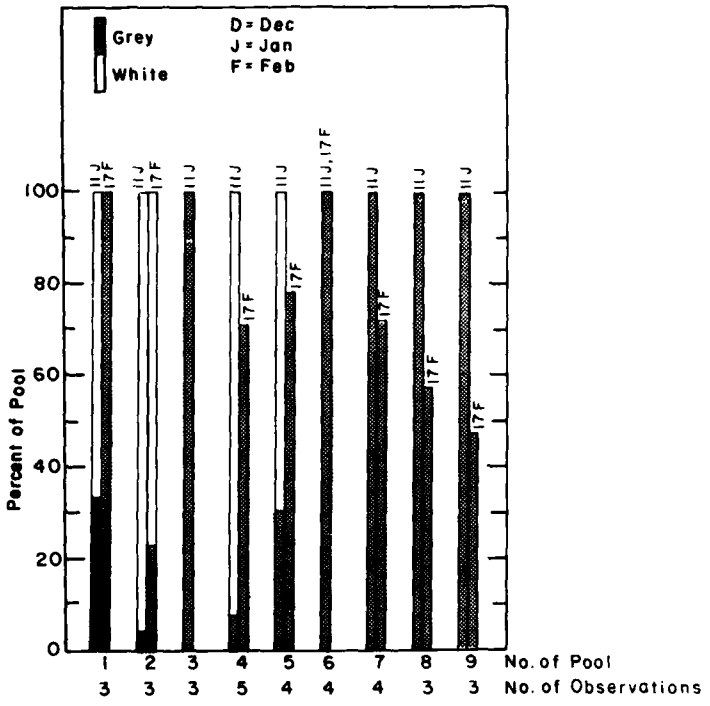
Not all the images were usable because clouds obscured the river on some of them. Consequently, the number of observations for a pool shown along the bottom of the bar graphs may not be the same as listed in Appendix C. For example, during the 1972–73 winter, Figure D1a shows three observations for pool 1 (L&D 9 pool) whereas Appendix C lists four. Complete cloud cover occurred on 18 November 1972 (App. C), so the Landsat image on this date was not included as an observation on the bar graph (Fig. D1a).

River pools to the end of the navigation channel.

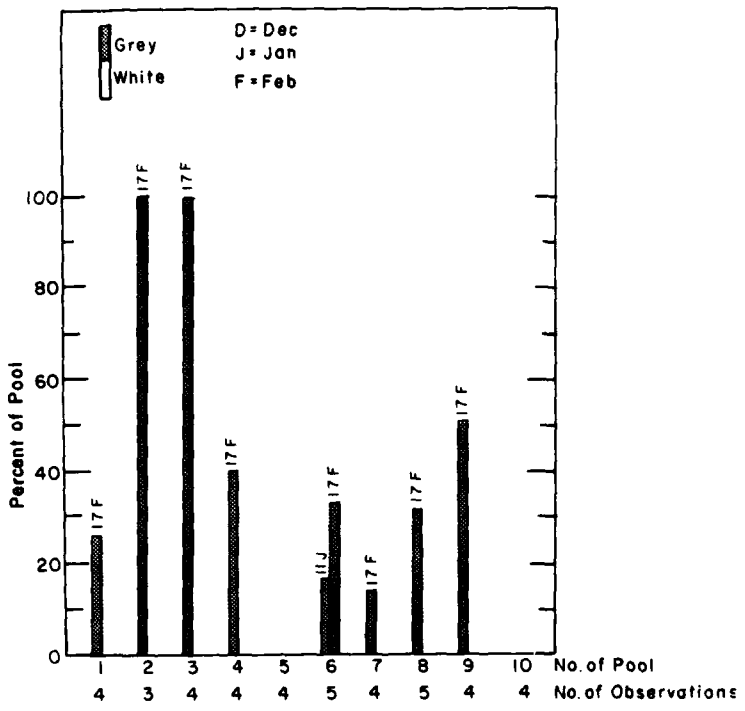
Pool no./ length (mi)	Pool start and stop points (river miles)	Approximate surface area* ($ft^2 x 10^6$)
	Allegheny River	
1/9.8	River mile 72 to L&D† 9(62.2)	38.81
2/9.6	L&D 9 to L&D 8 (52.6)	43.09
3/6.9	L&D 8 to L&D 7(45.7)	34.61
4/9.4	L&D 7 to L&D 6(36.3)	47.15
5/5.9	L&D 6 to L&D 5(30.4)	24.92
6/6.2	L&D 5 to L&D 4(24.2)	31.10
7/9.7	L&D 4 to L&D 3(14.5)	56.34
8/7.8	L&D 3 to L&D 2(6.7)	43.22
9/6.7	L&D 2 to Pittsburgh Point(0)	33.05
	Monongahela River	
1/13.3	River mile 128.7 to Opekiska L&D (115.4)	31.60
2/7.4	Opekiska L&D to Hildebrand L&D (108)	17.58
3/6.0	Hildebrand L&D to Morgantown L&D (102)	17.42
4/11.2	Morgantown L&D to L&D 8(90.8)	32.53
5/5.8	L&D 8 to L&D 7(85)	19.91
6/23.8	L&D 7 to Maxwell L&D (61.2)	81.68
7/19.7	Maxwell L&D to L&D 4(41.5)	71.04
8/17.7	L&D 4 to L&D 3(23.8)	71.47
9/12.6	L&D 3 to L&D 2(11.2)	51.34
10/11.2	L&D 2 to Pittsburgh Point (0)	50.91

* When the water level is at normal pool elevation.

†L&D means lock and dam.



a. Allegheny River.



b. Monongahela River.

Figure D1. 1972–73 winter.

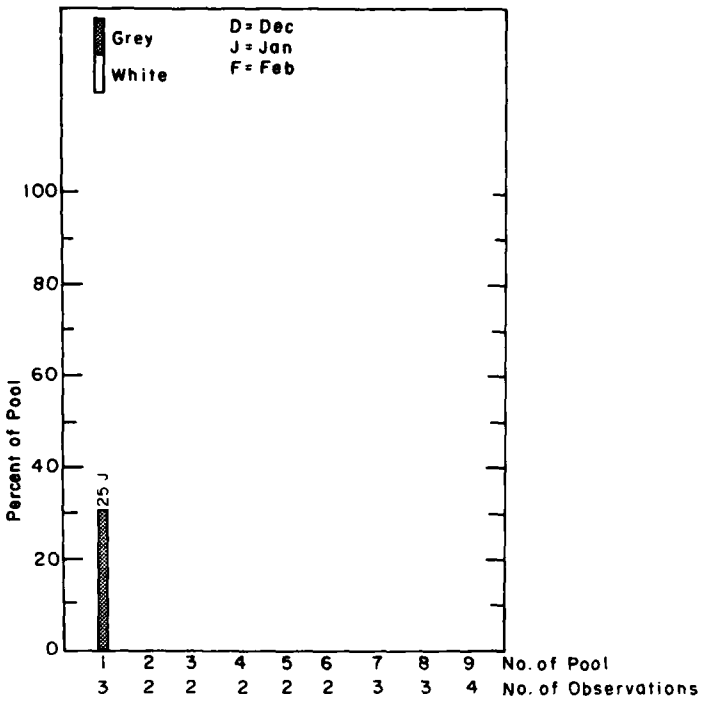


Figure D2. 1973–74 winter, Allegheny River.

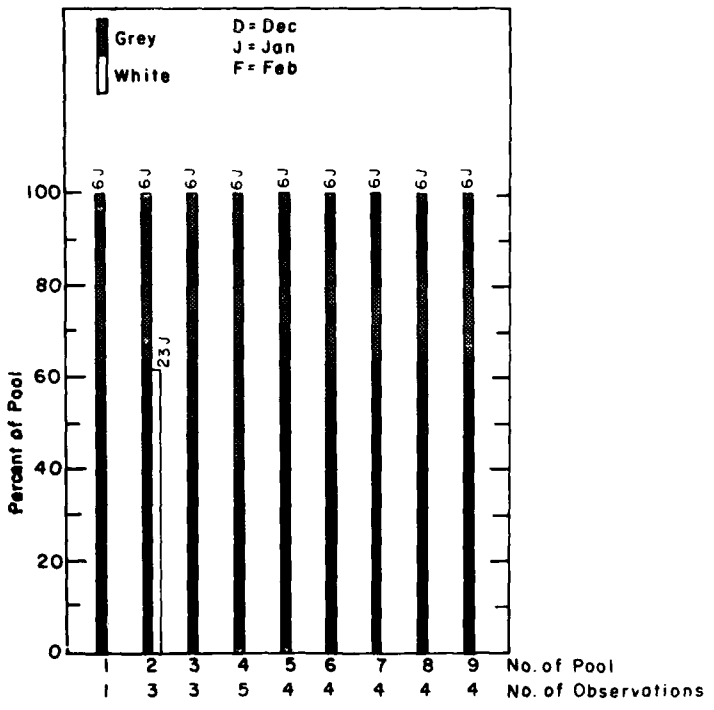
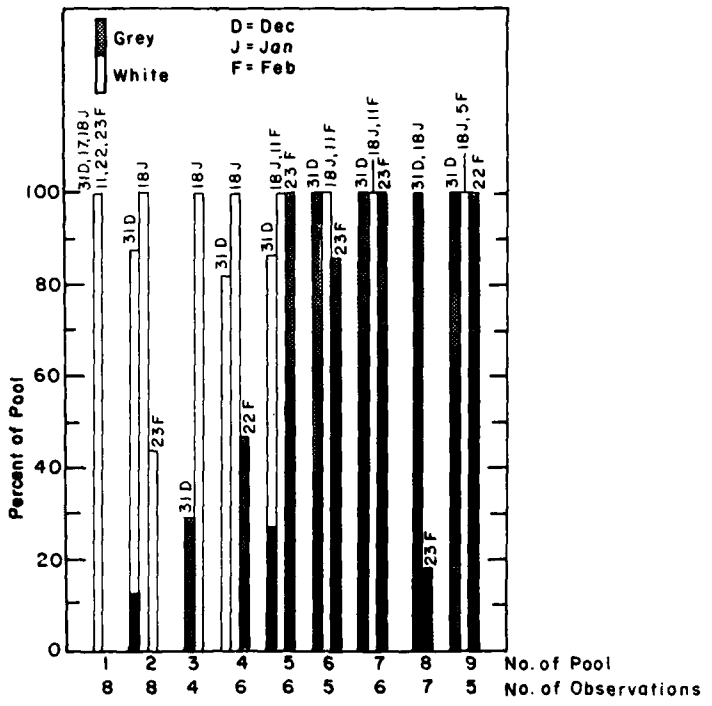
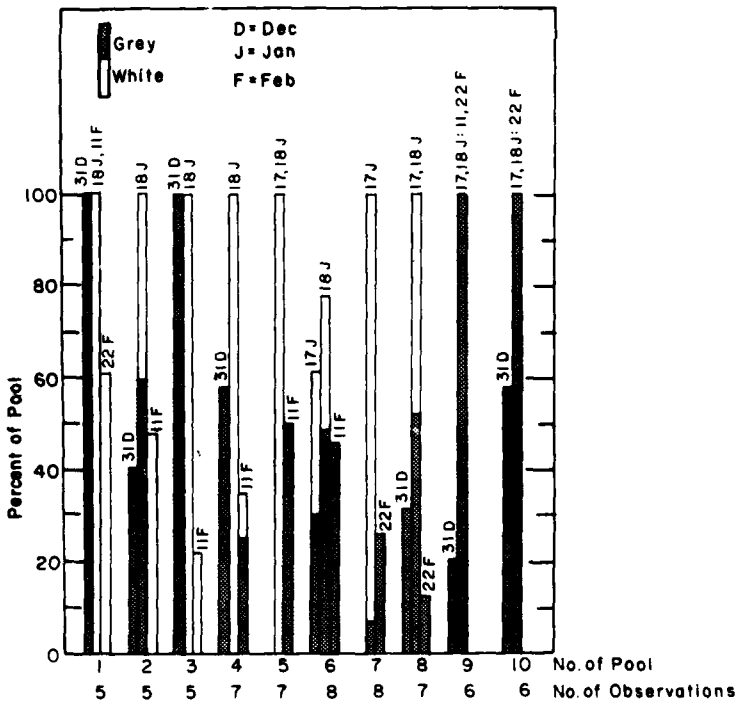


Figure D3. 1975–76 winter, Allegheny River.

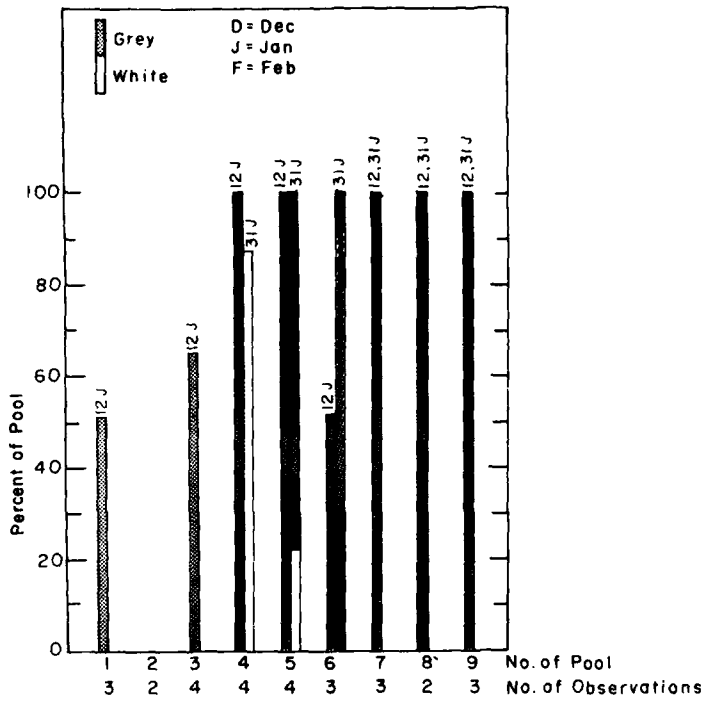


a. Allegheny River.

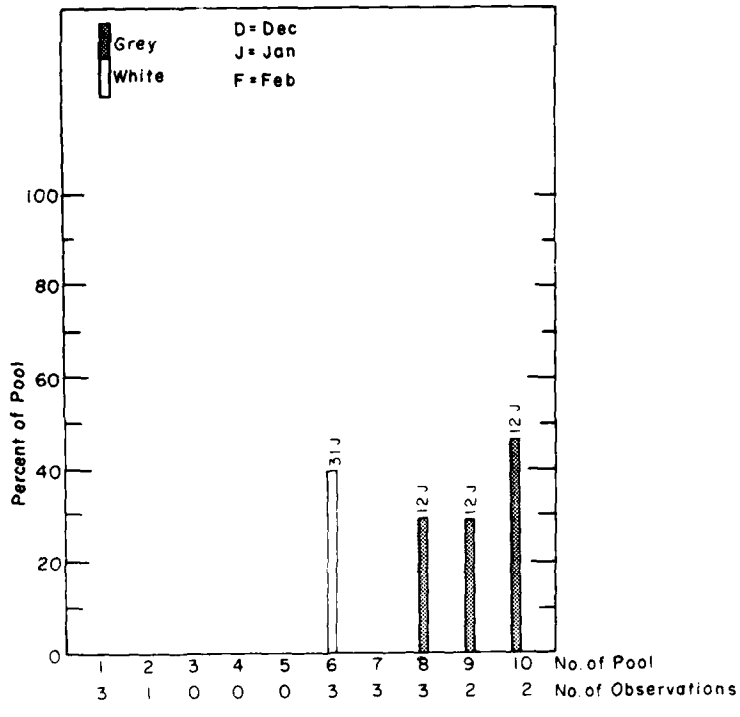


b. Monongahela River.

Figure D4. 1976–77 winter.



a. Allegheny River.



b. Monongahela River.

Figure D5. 1977-78 winter.

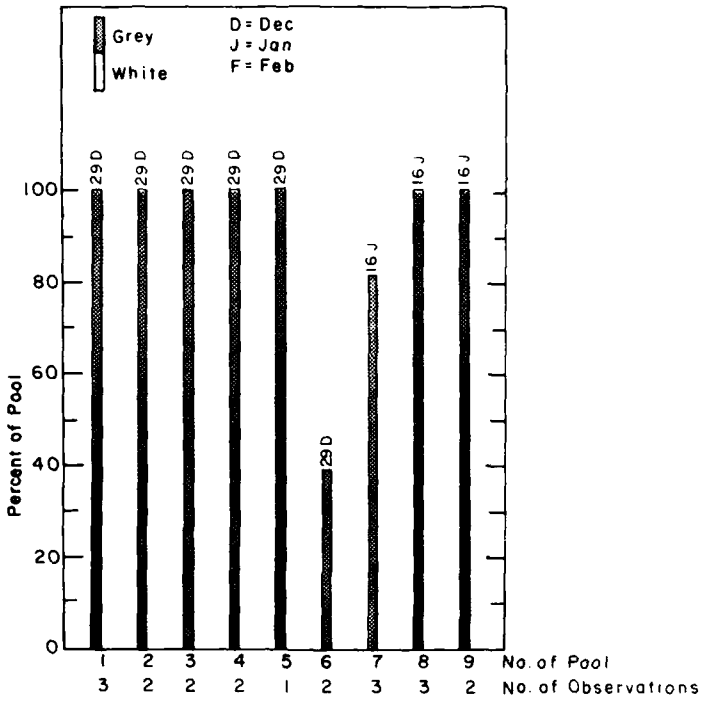
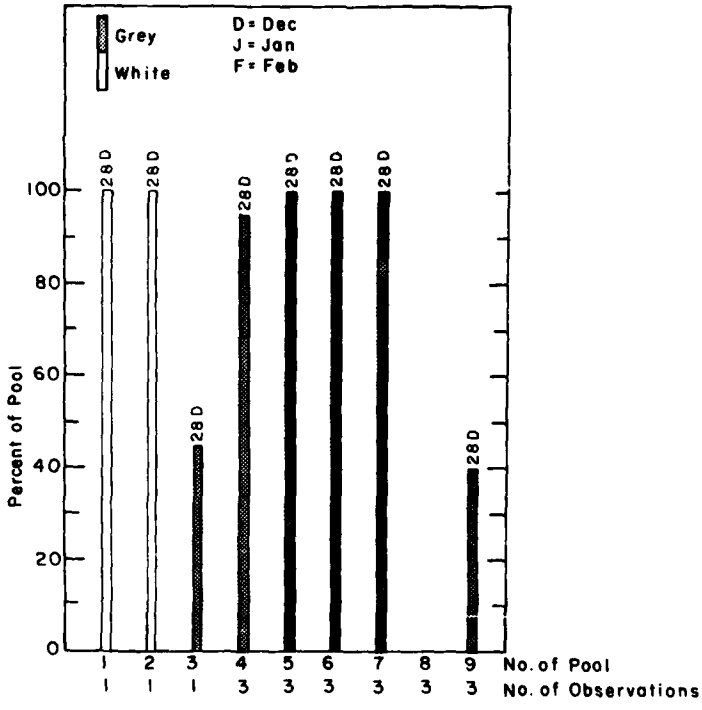
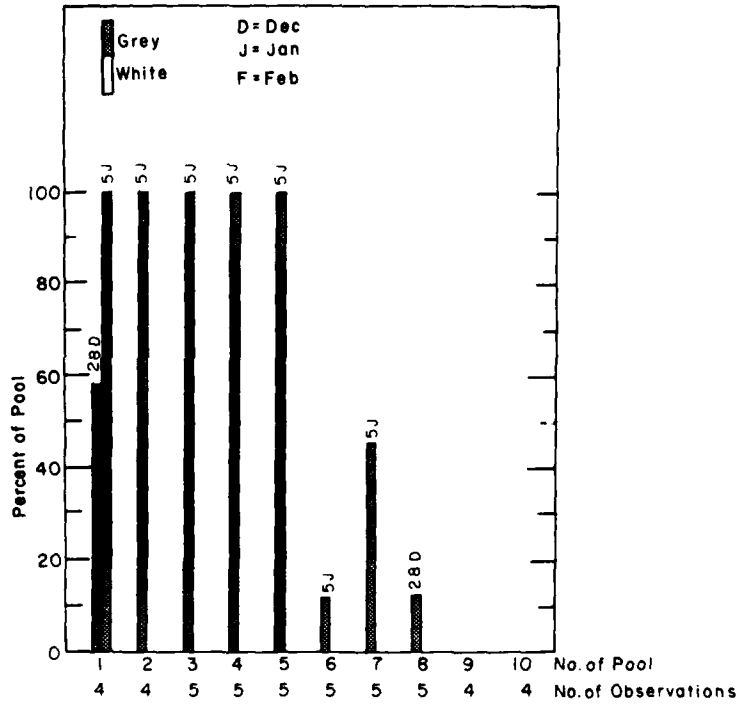


Figure D6. 1978-79 winter, Allegheny River.



a. Allegheny River.



b. Monongahela River.

Figure D7. 1980–81 winter.

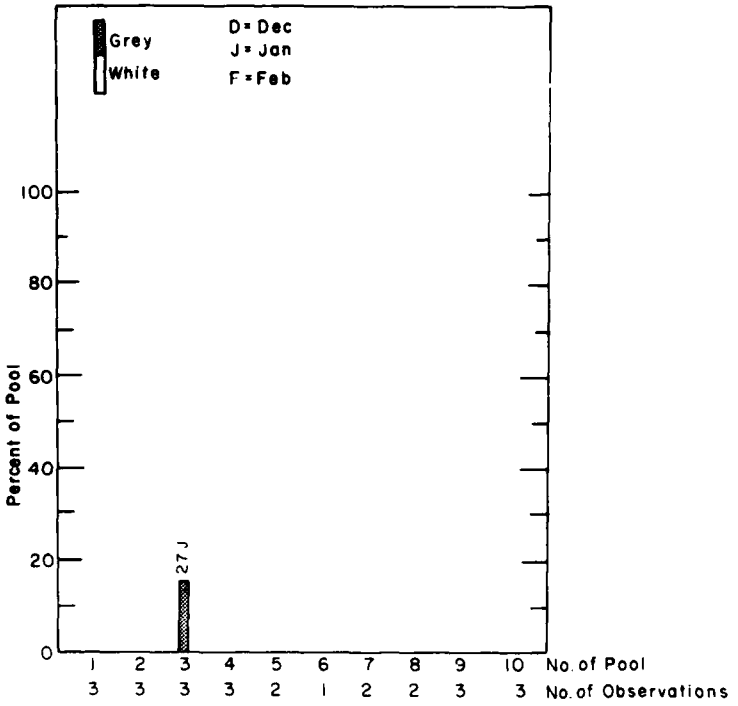


Figure D8. 1981–82 winter, Monongahela River.

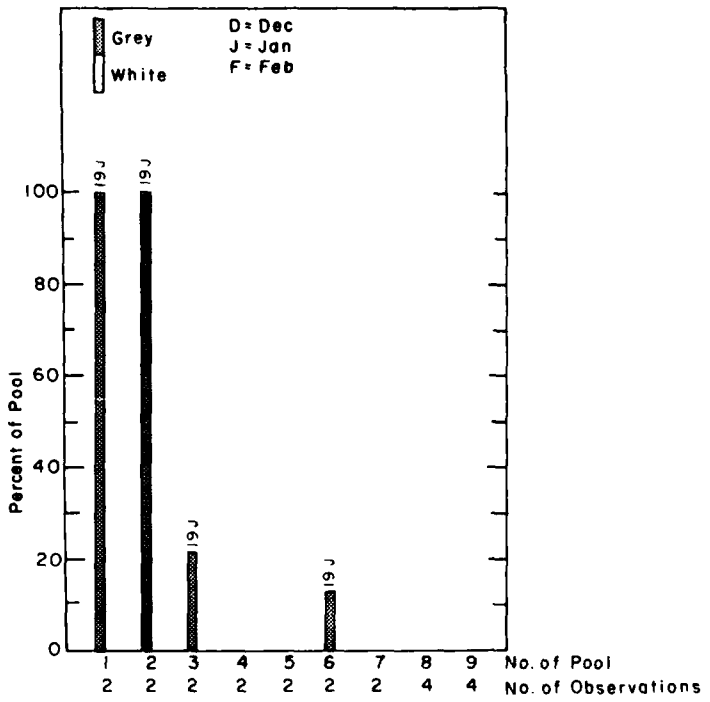
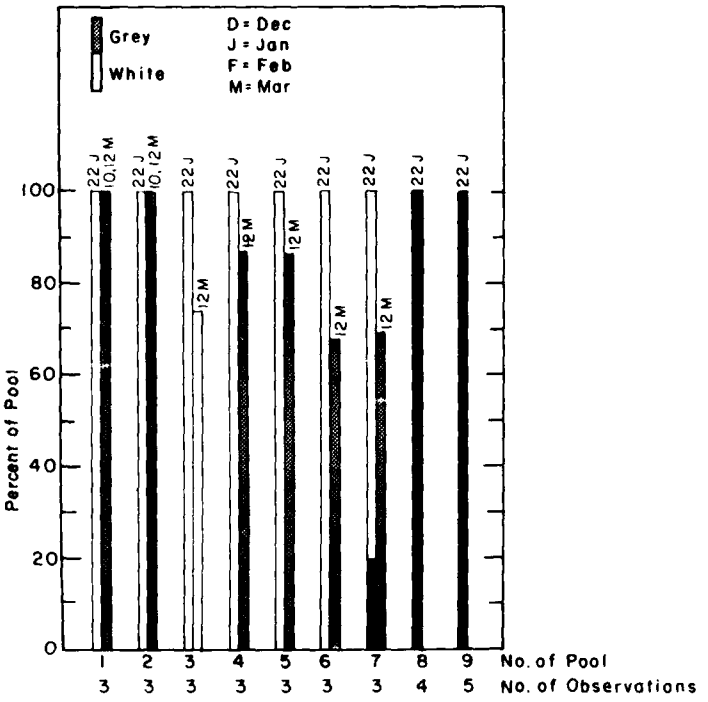
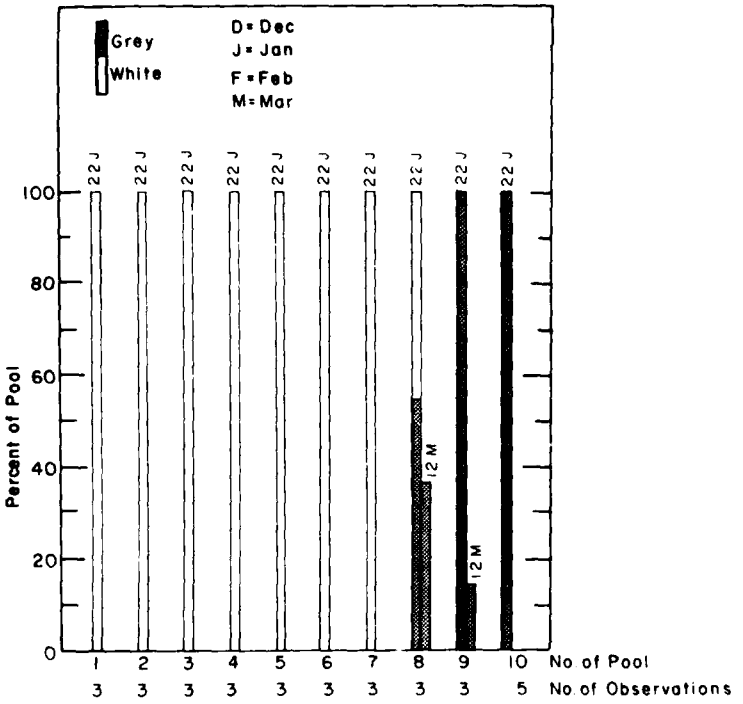


Figure D9. 1982–83 winter, Allegheny River.

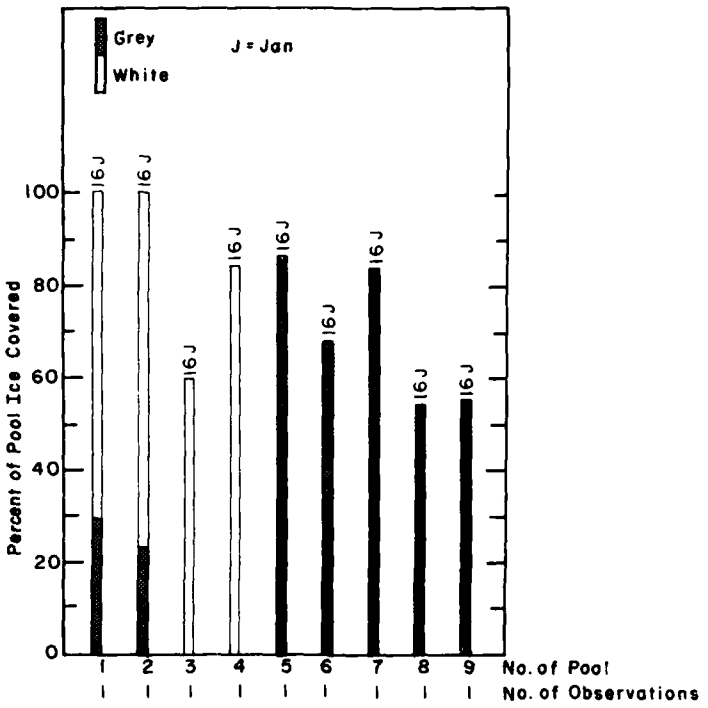


a. Allegheny River.

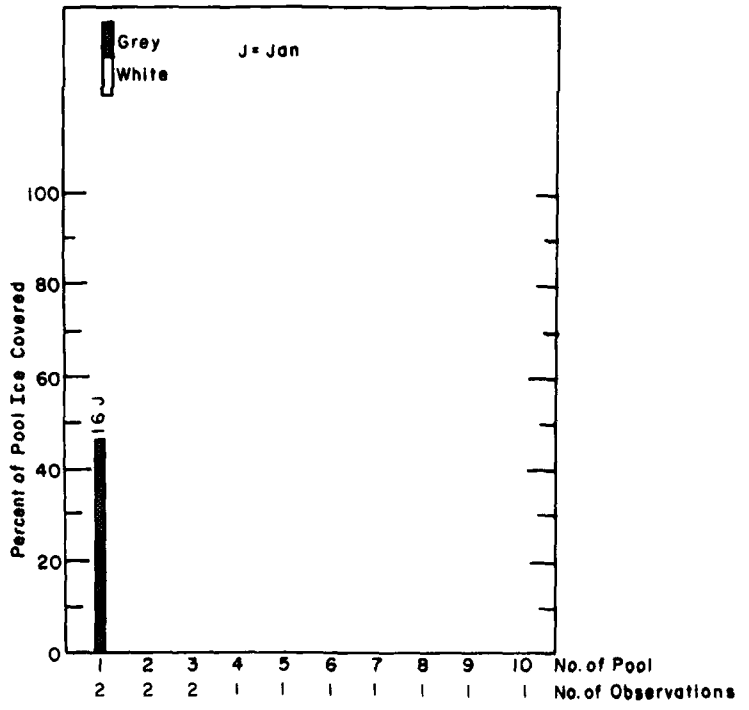


b. Monongahela River.

Figure D10. 1983–84 winter.



a. Allegheny River.



b. Monongahela River.

Figure D11. 1984–85 winter.

APPENDIX E: AIR TEMPERATURE, WATER TEMPERATURE AND DISCHARGES

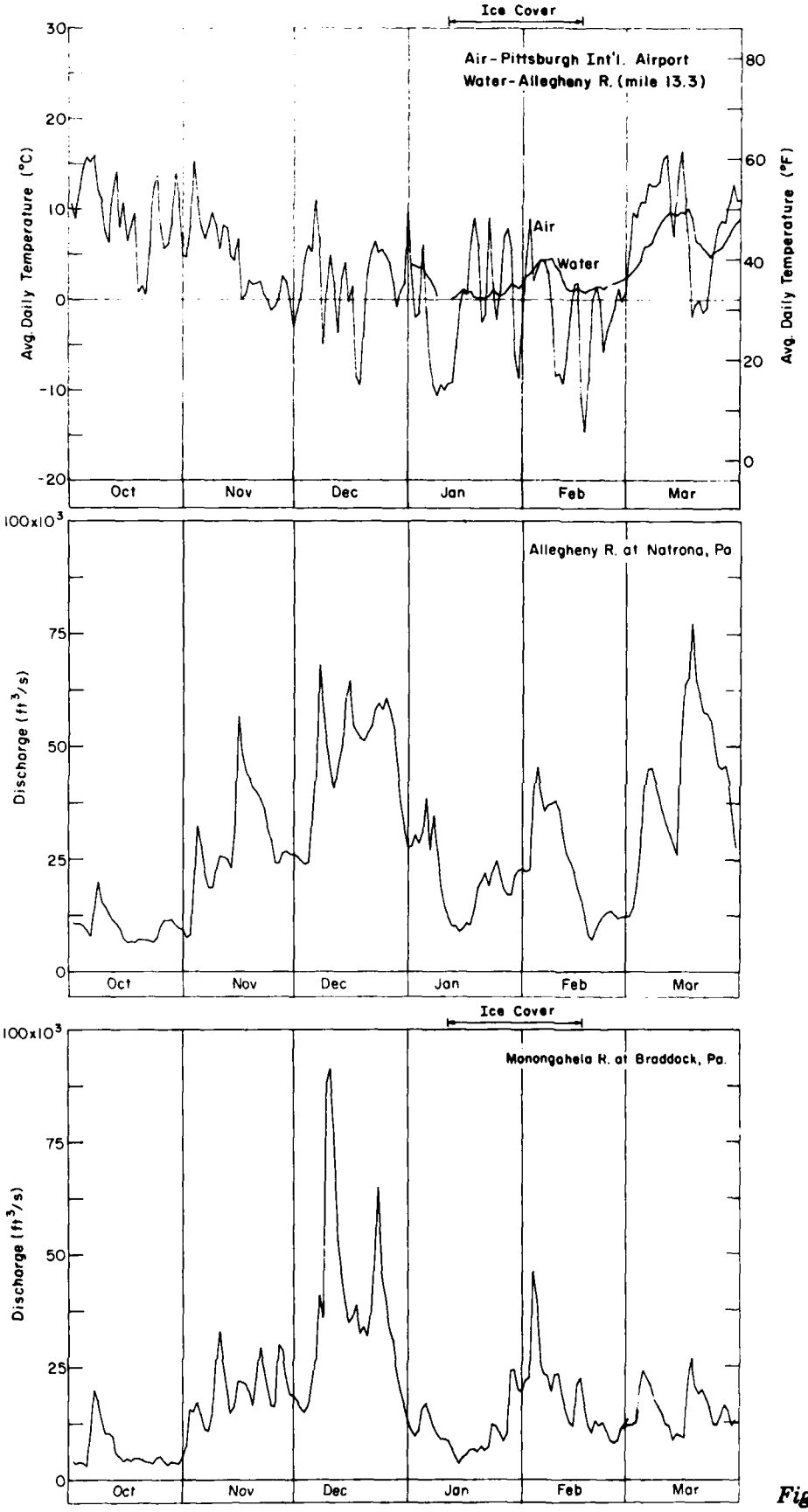


Figure E1. 1972–73.

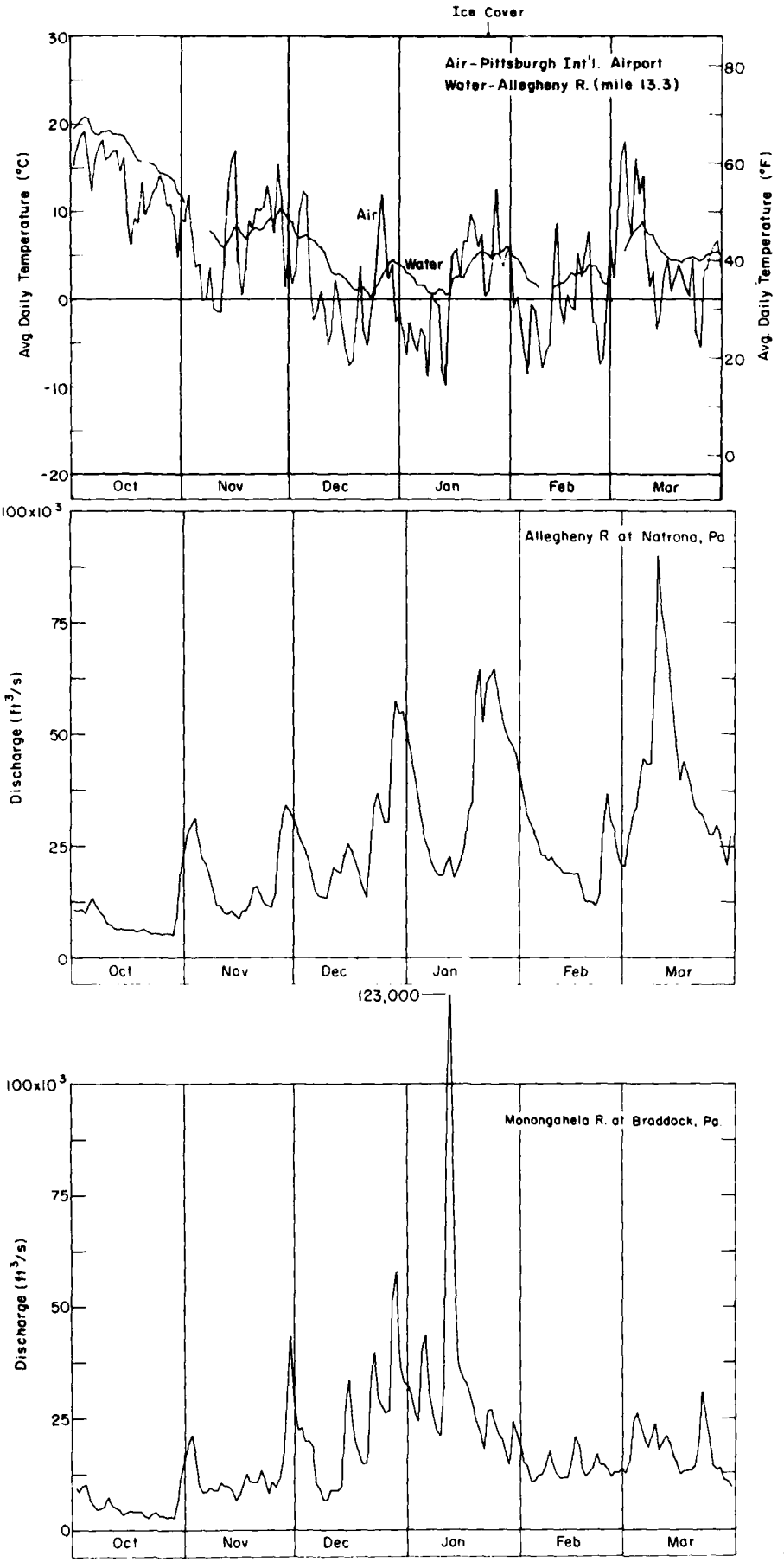


Figure E2. 1973-74.

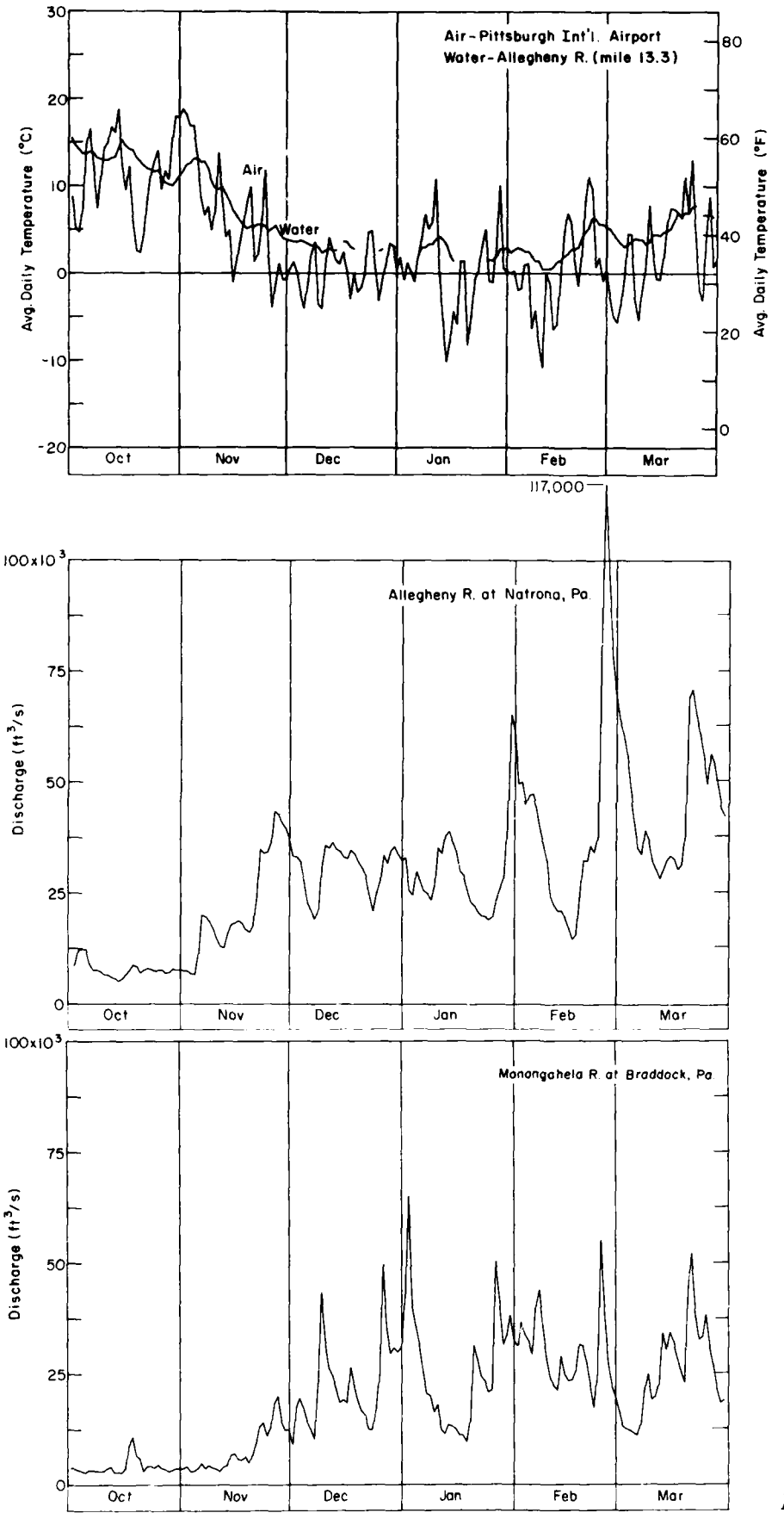


Figure E3. 1974–75.

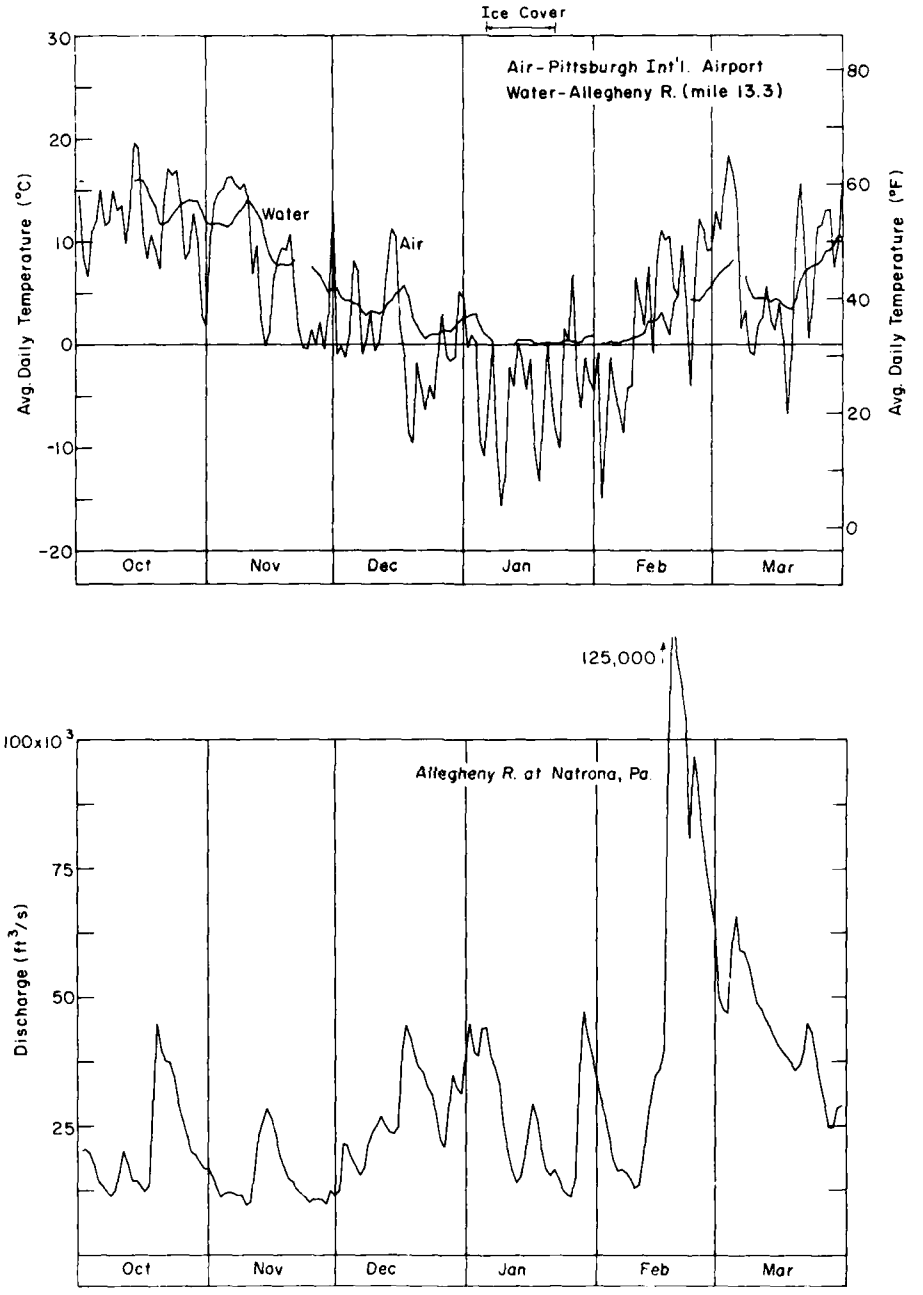


Figure E4. 1975–76.

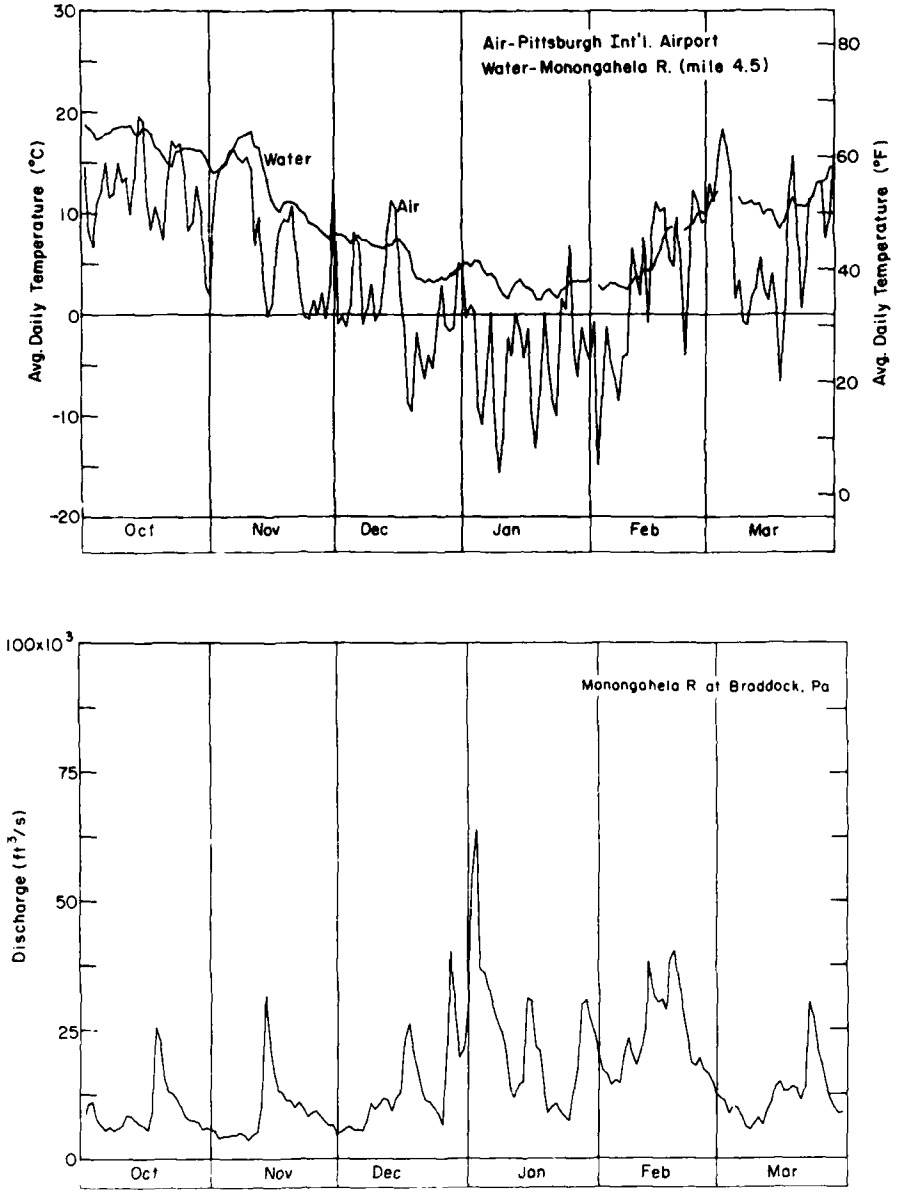


Figure E4 (cont'd).

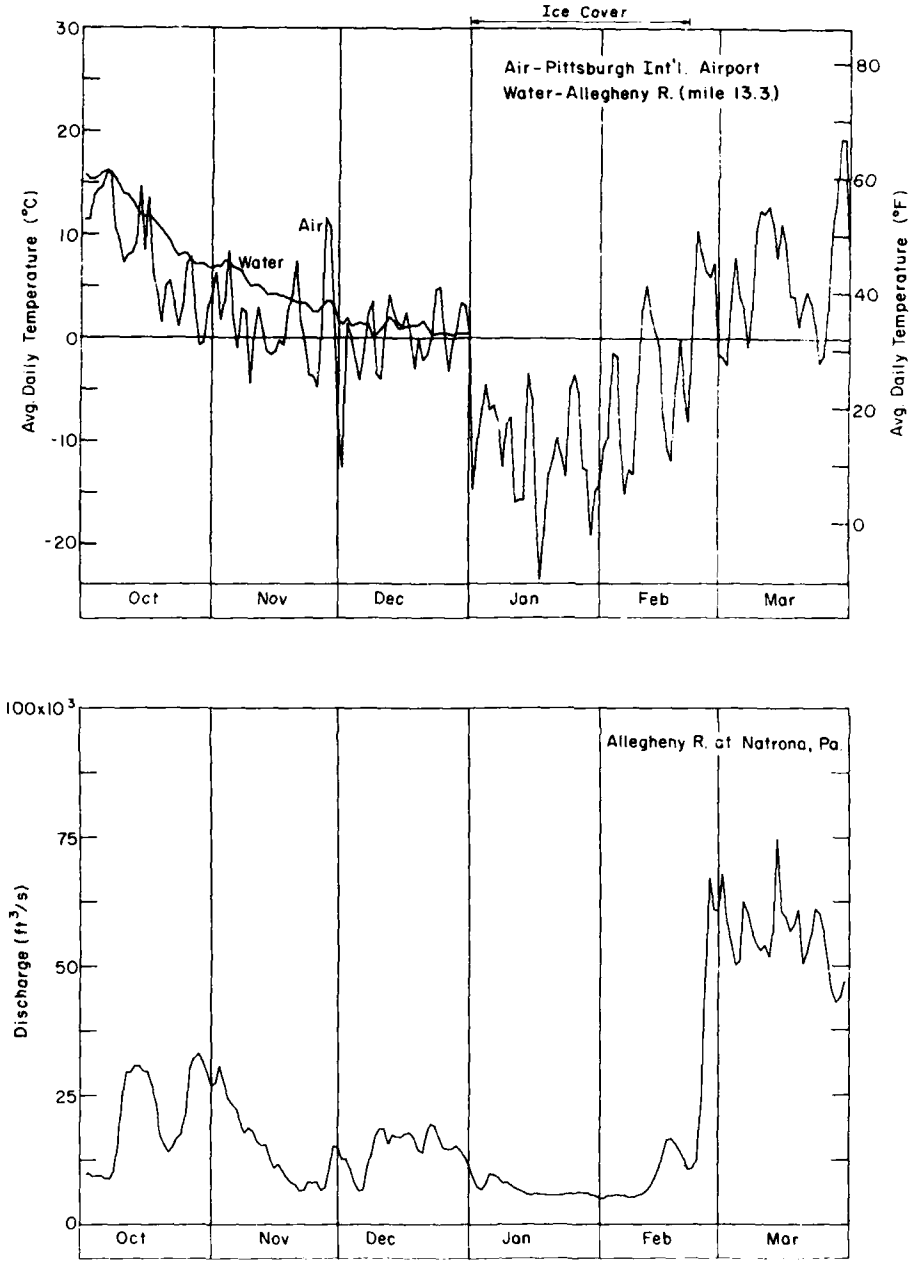


Figure E5. 1976–77.

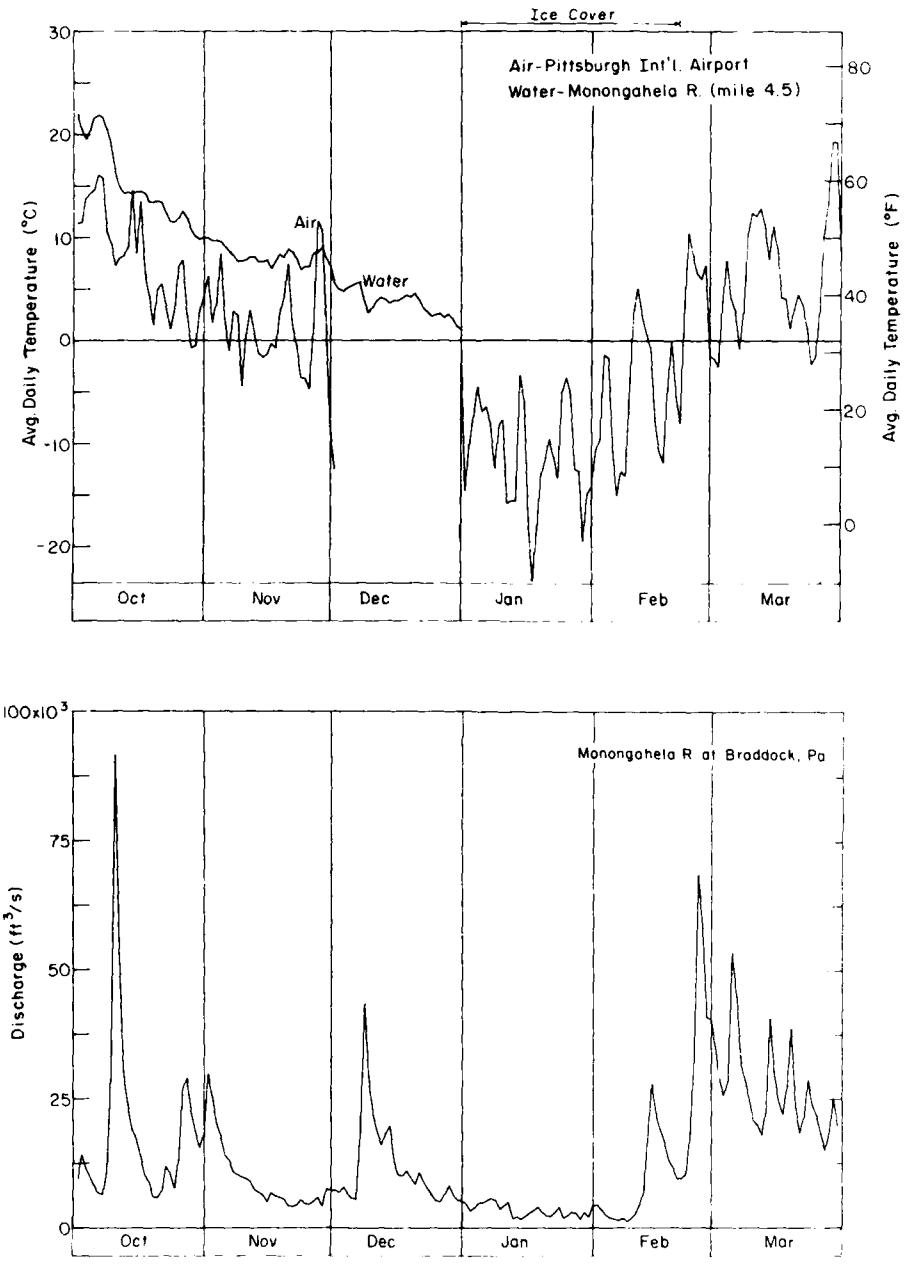


Figure E5 (cont'd).

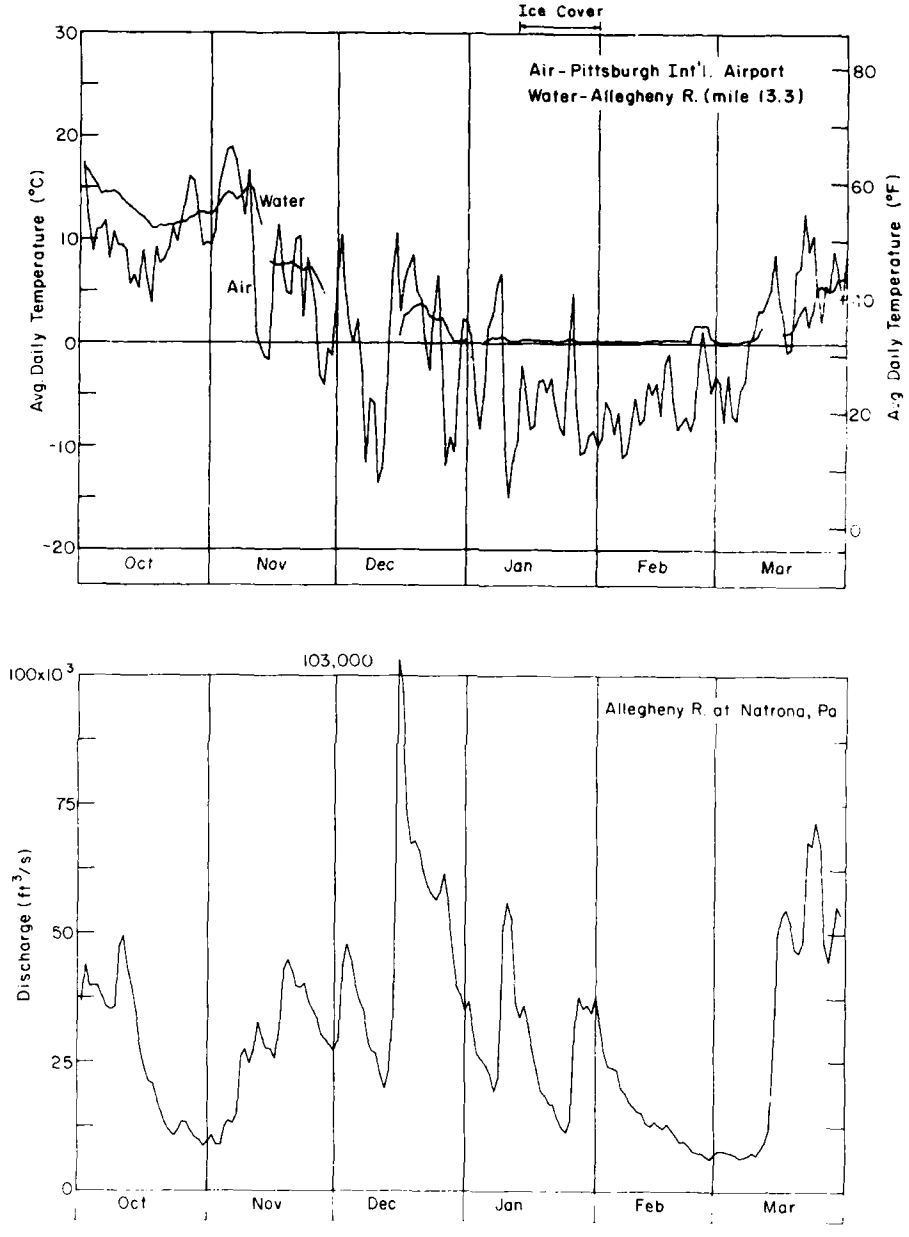


Figure E6. 1977–78.

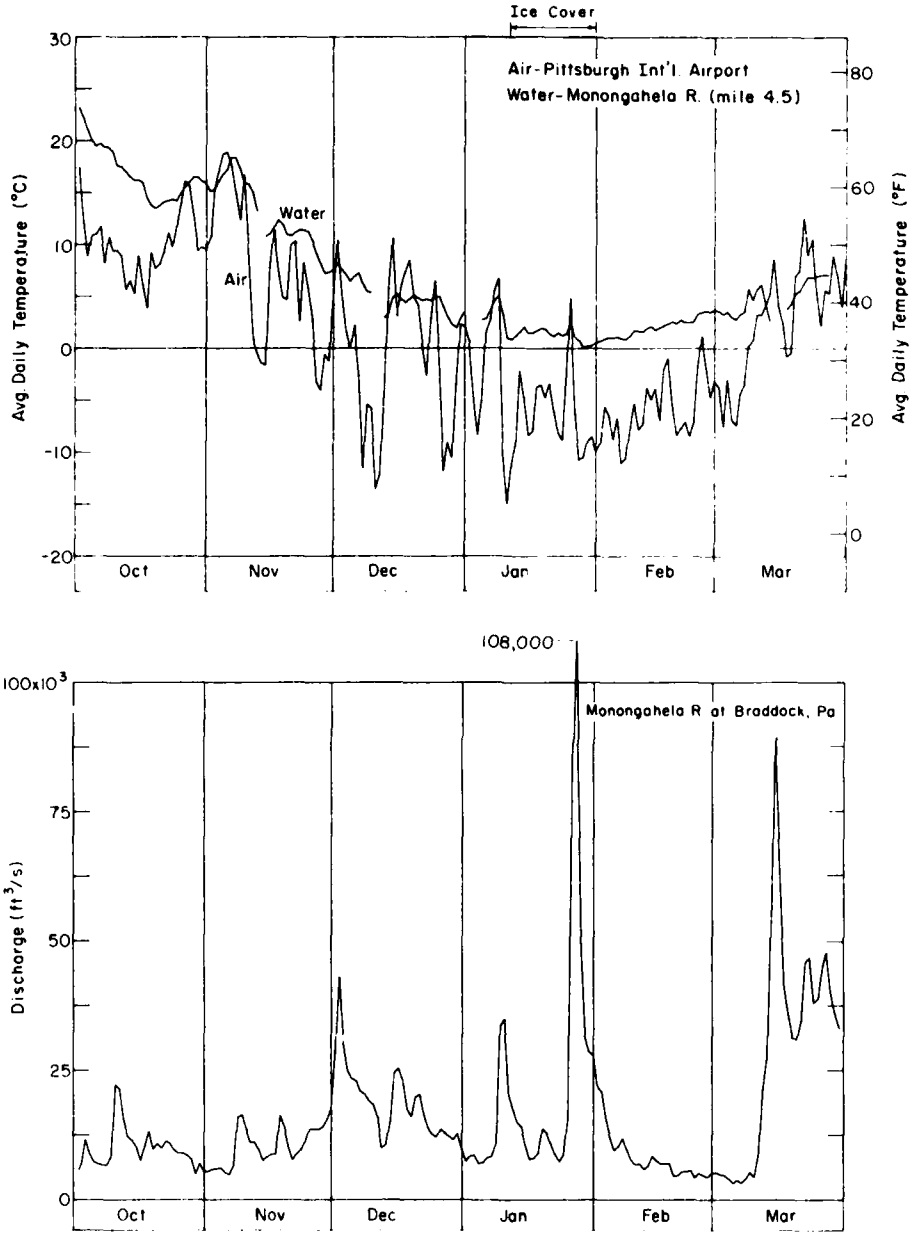


Figure E6 (cont'd).

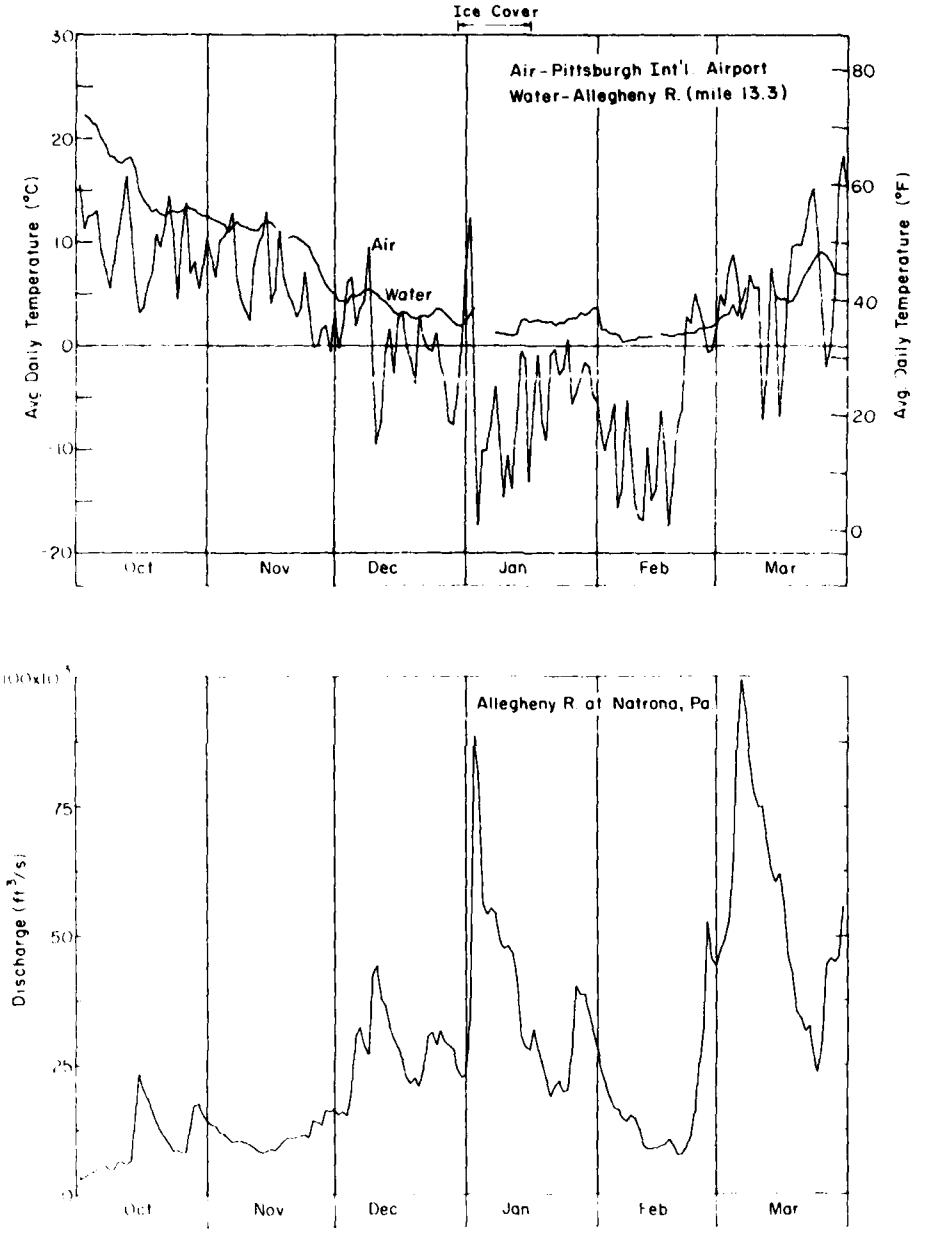


Figure E7. 1978–79.

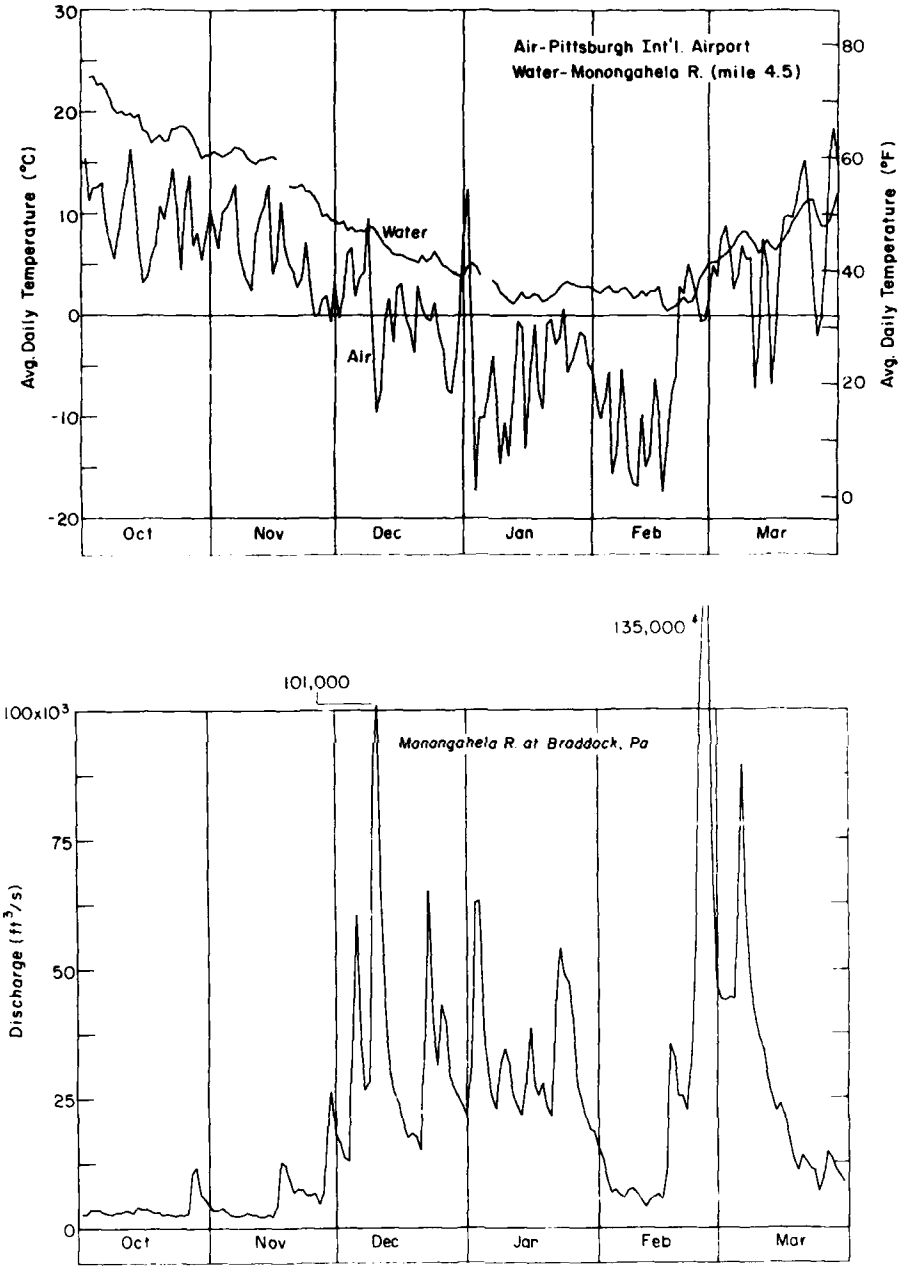


Figure E7 (cont'd).

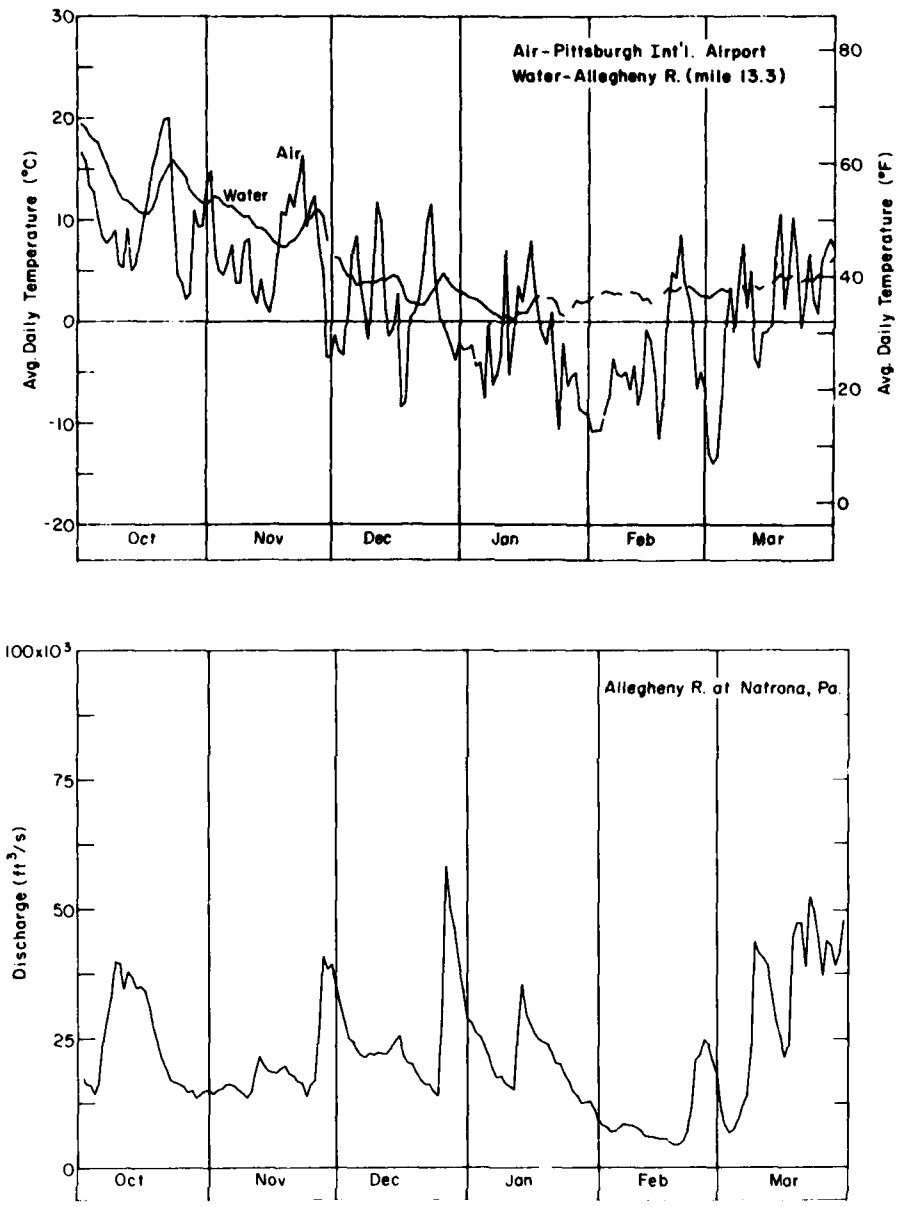


Figure E8. 1979–80.

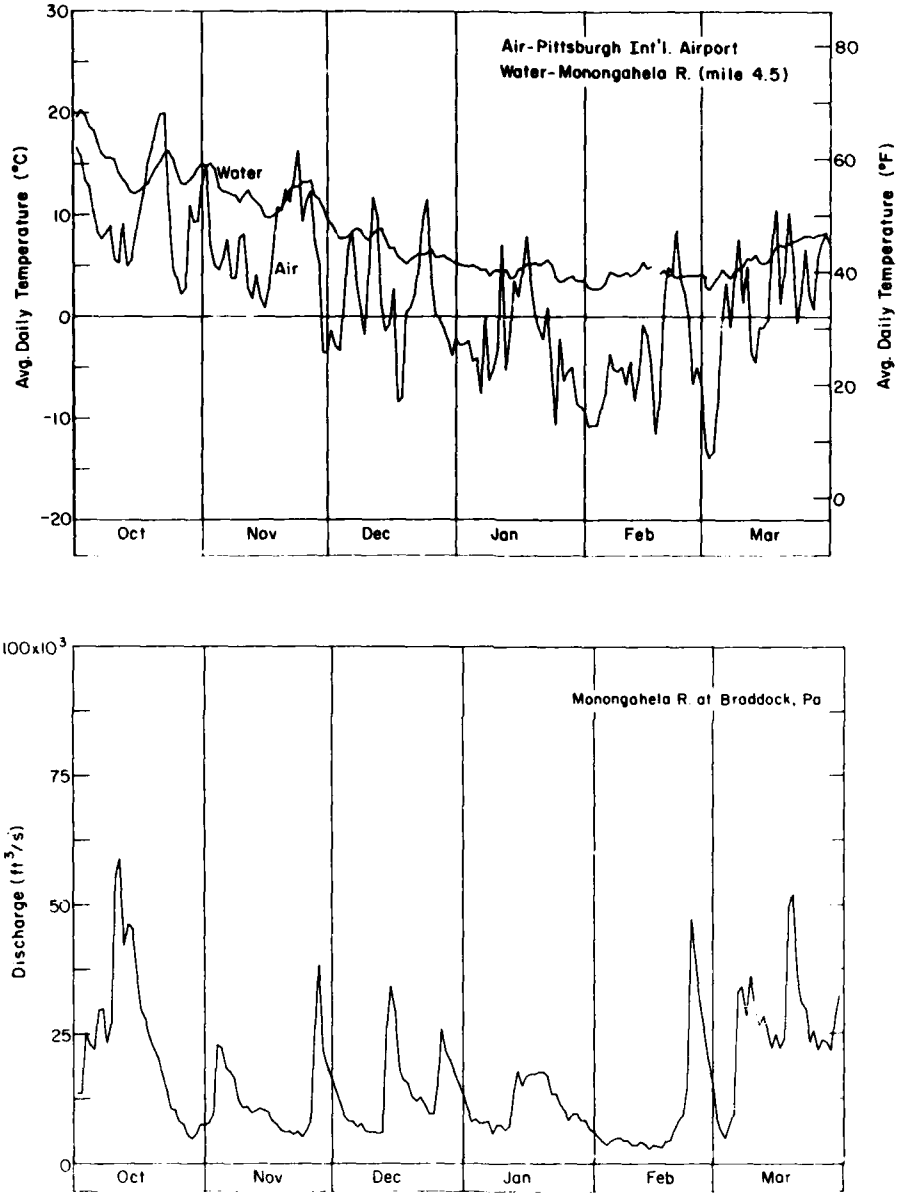


Figure E8 (cont'd).

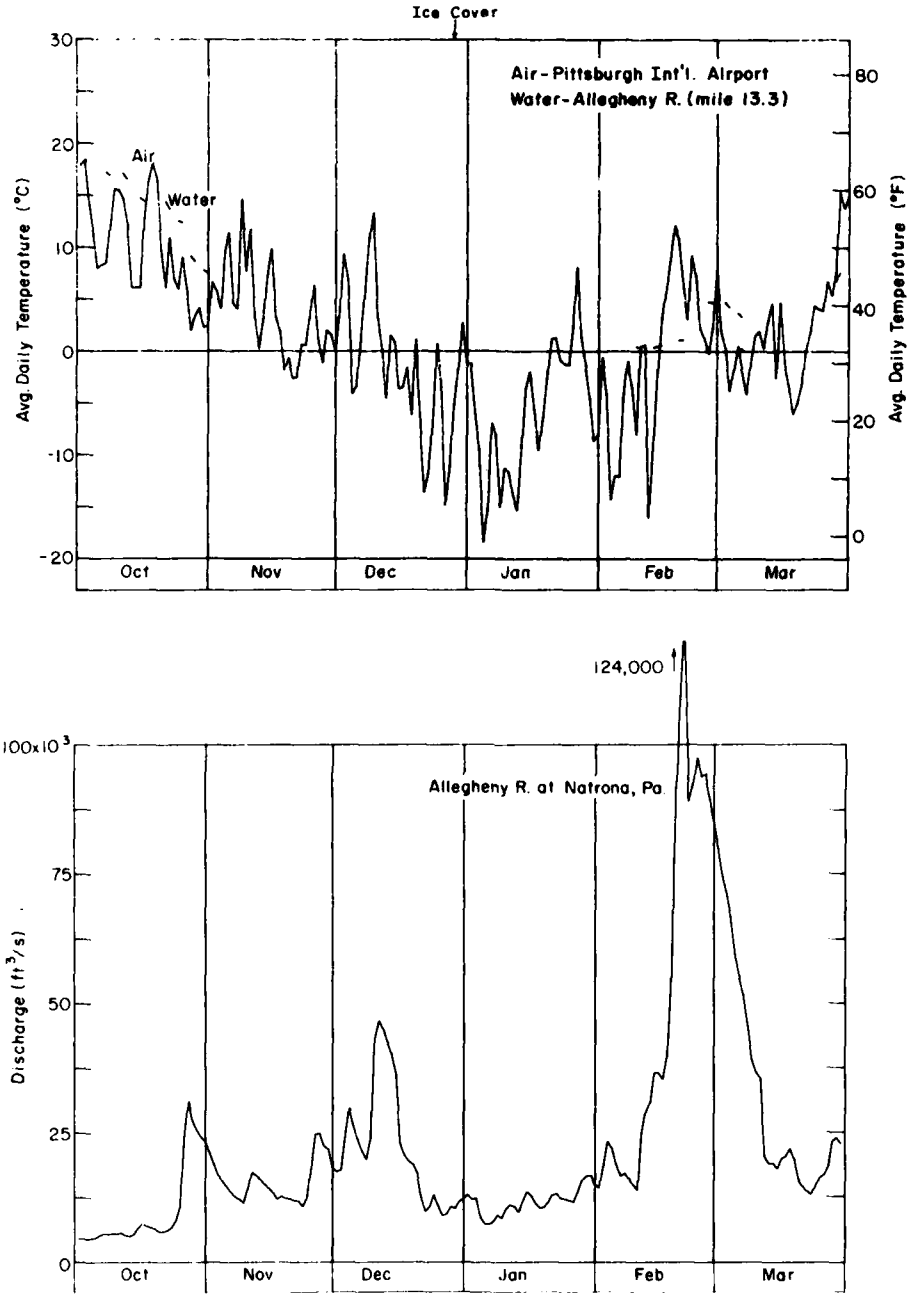


Figure E9. 1980–81.

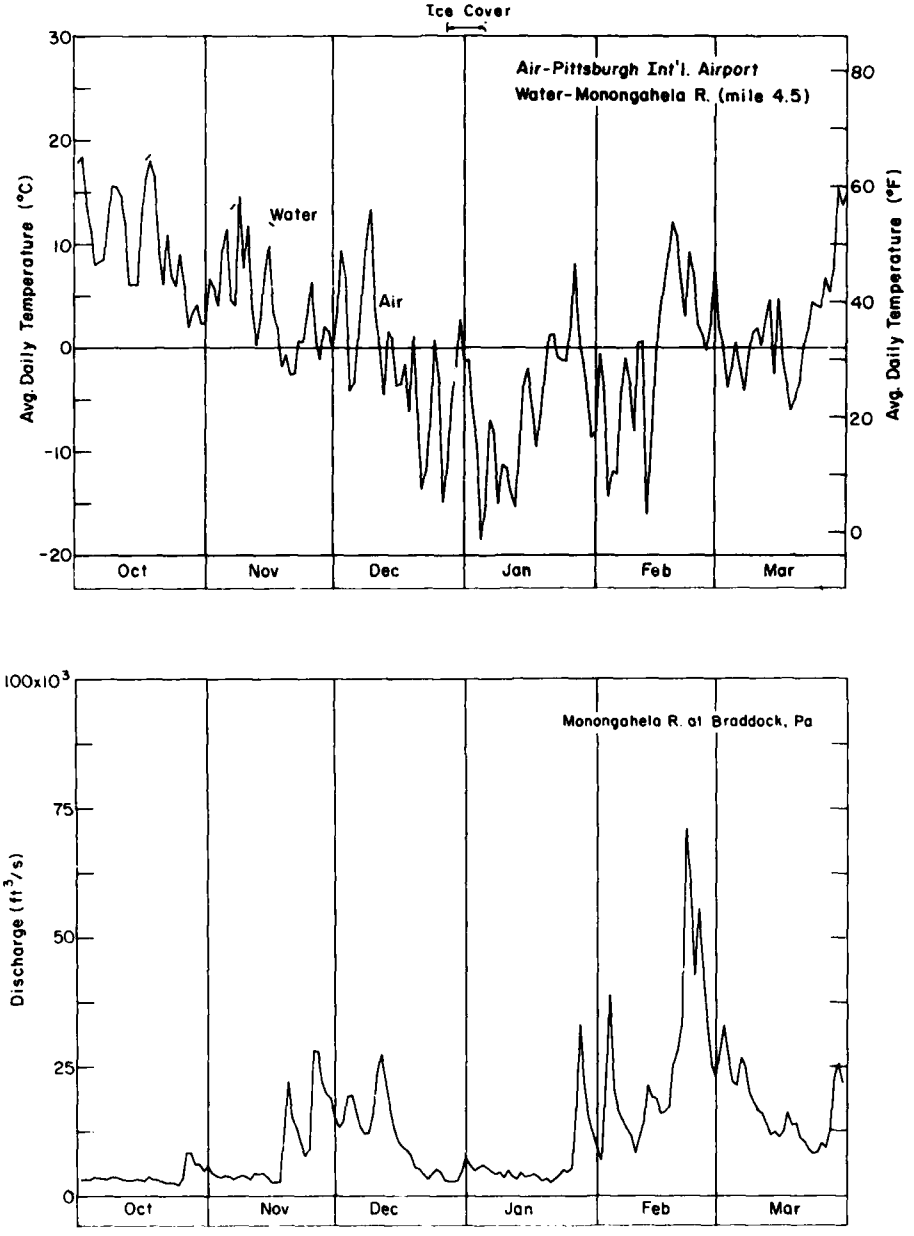


Figure E9 (cont'd).

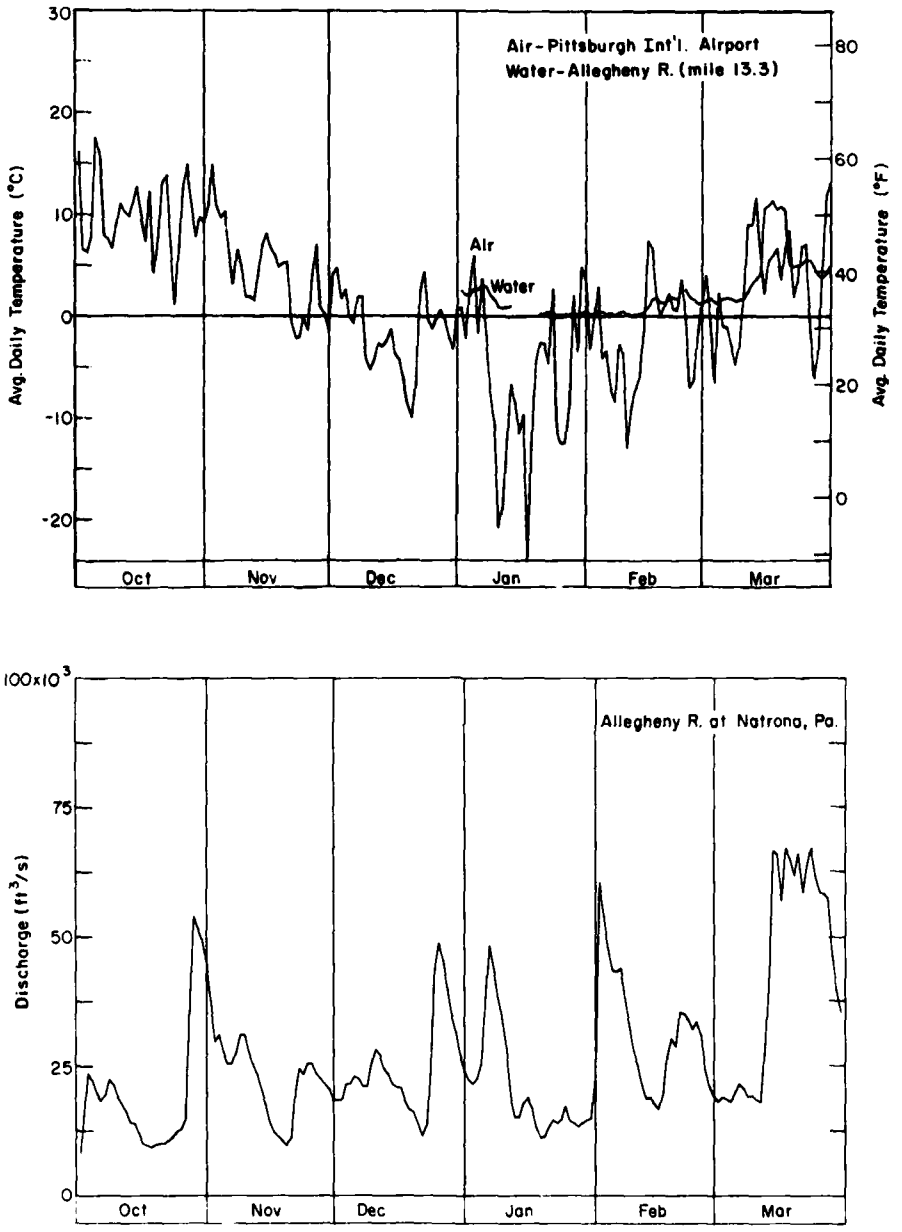


Figure E10. 1981–82.

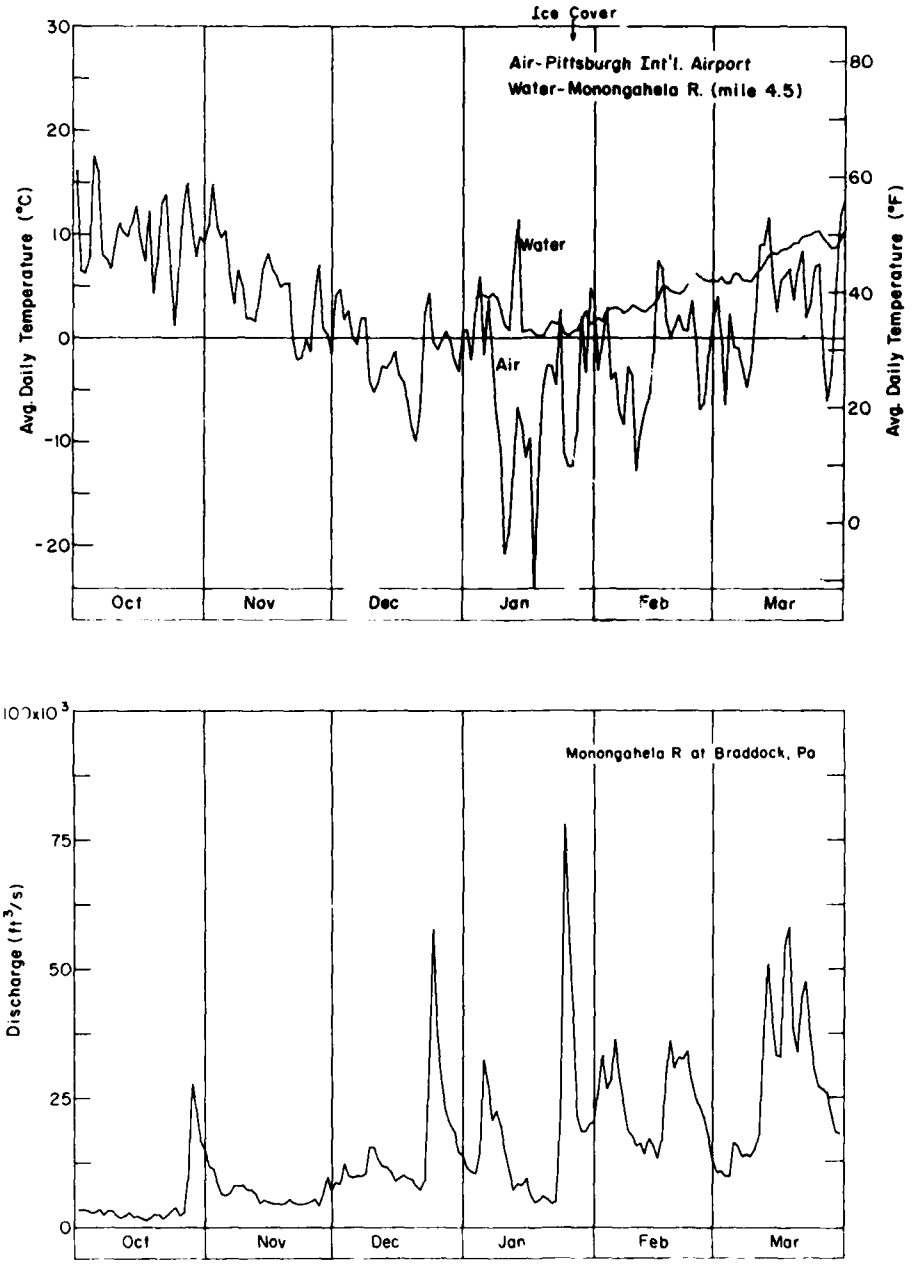


Figure E10 (cont'd).

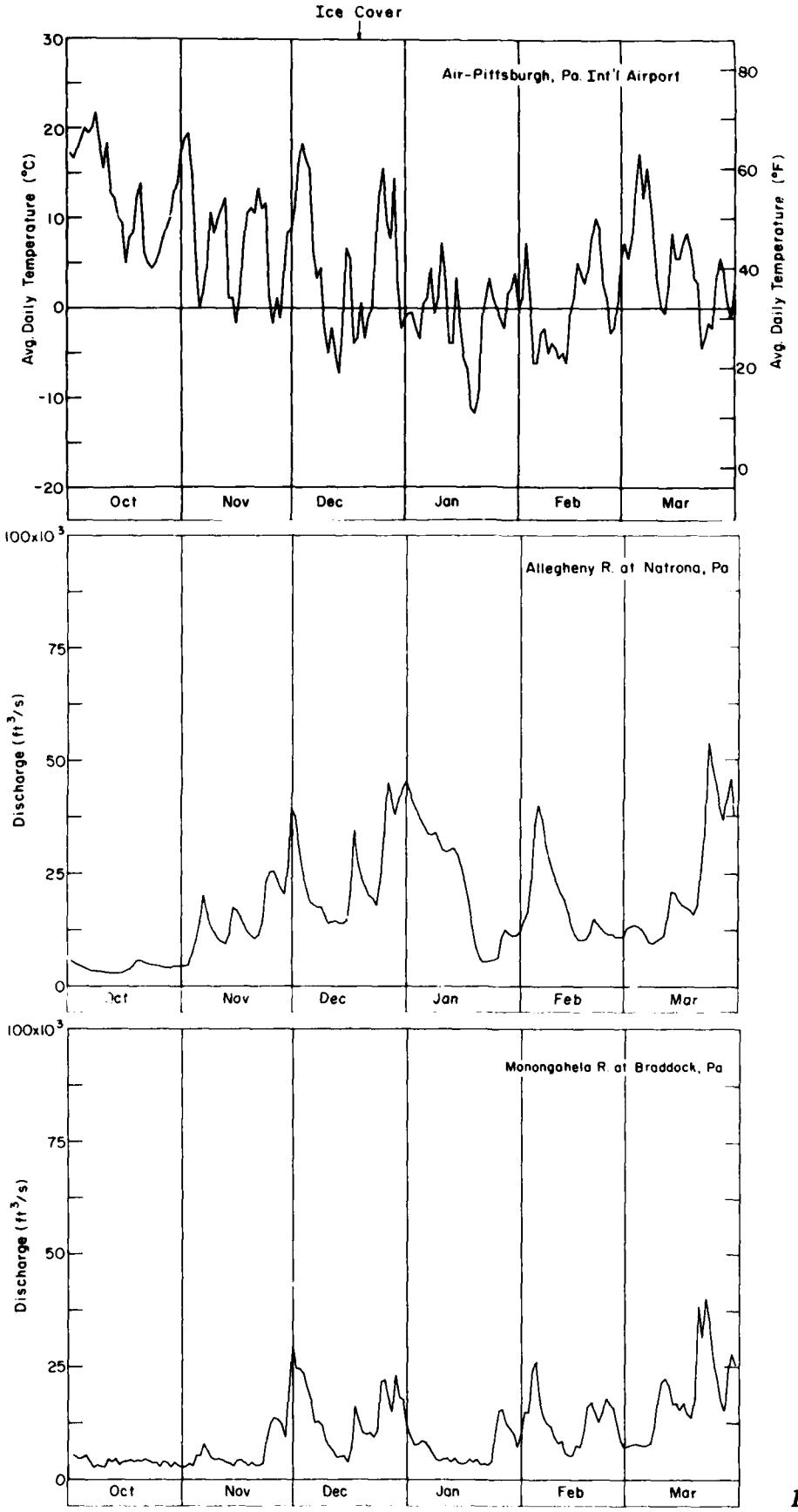


Figure E11. 1982–83.

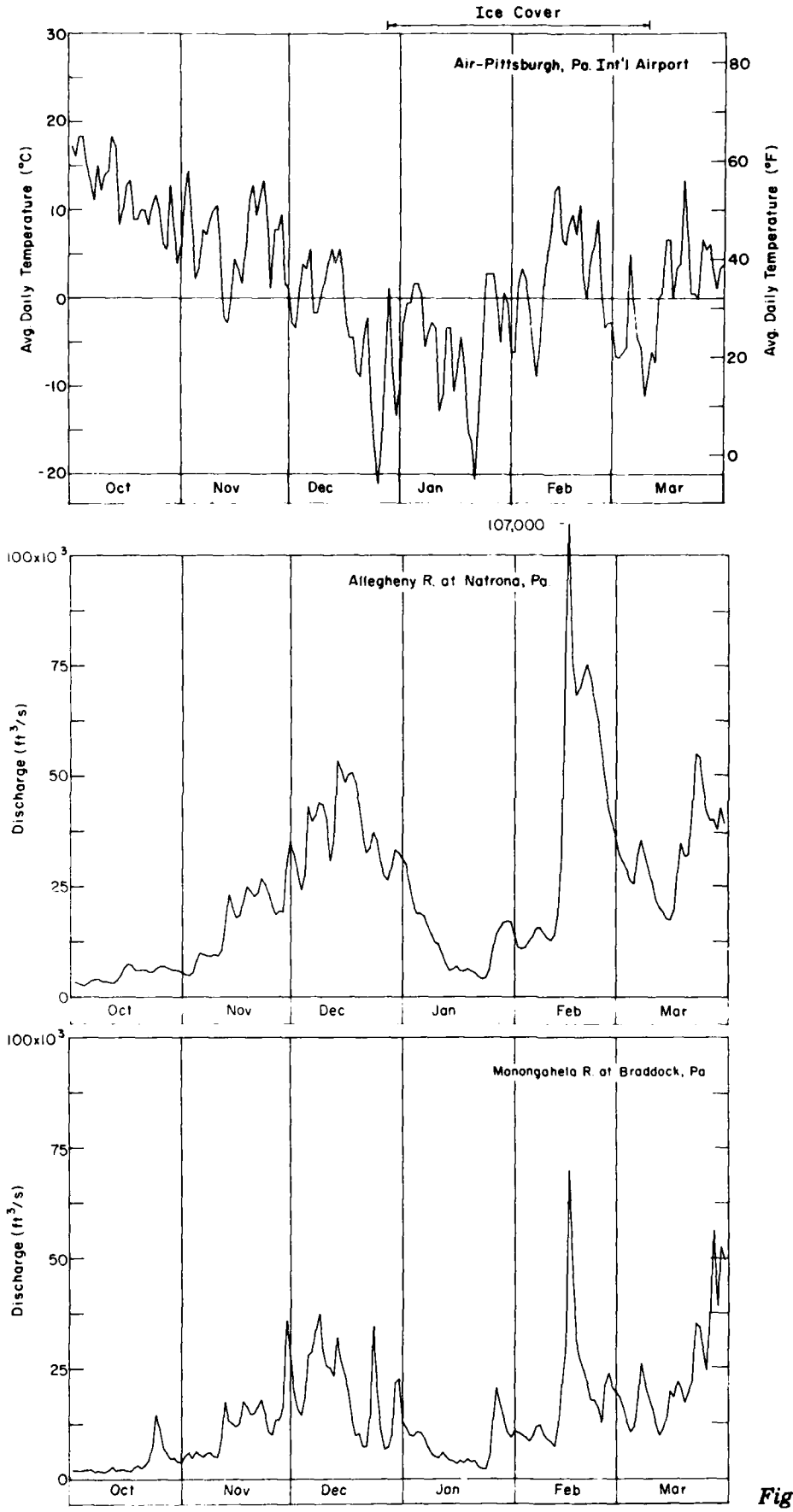


Figure E12. 1983–84.

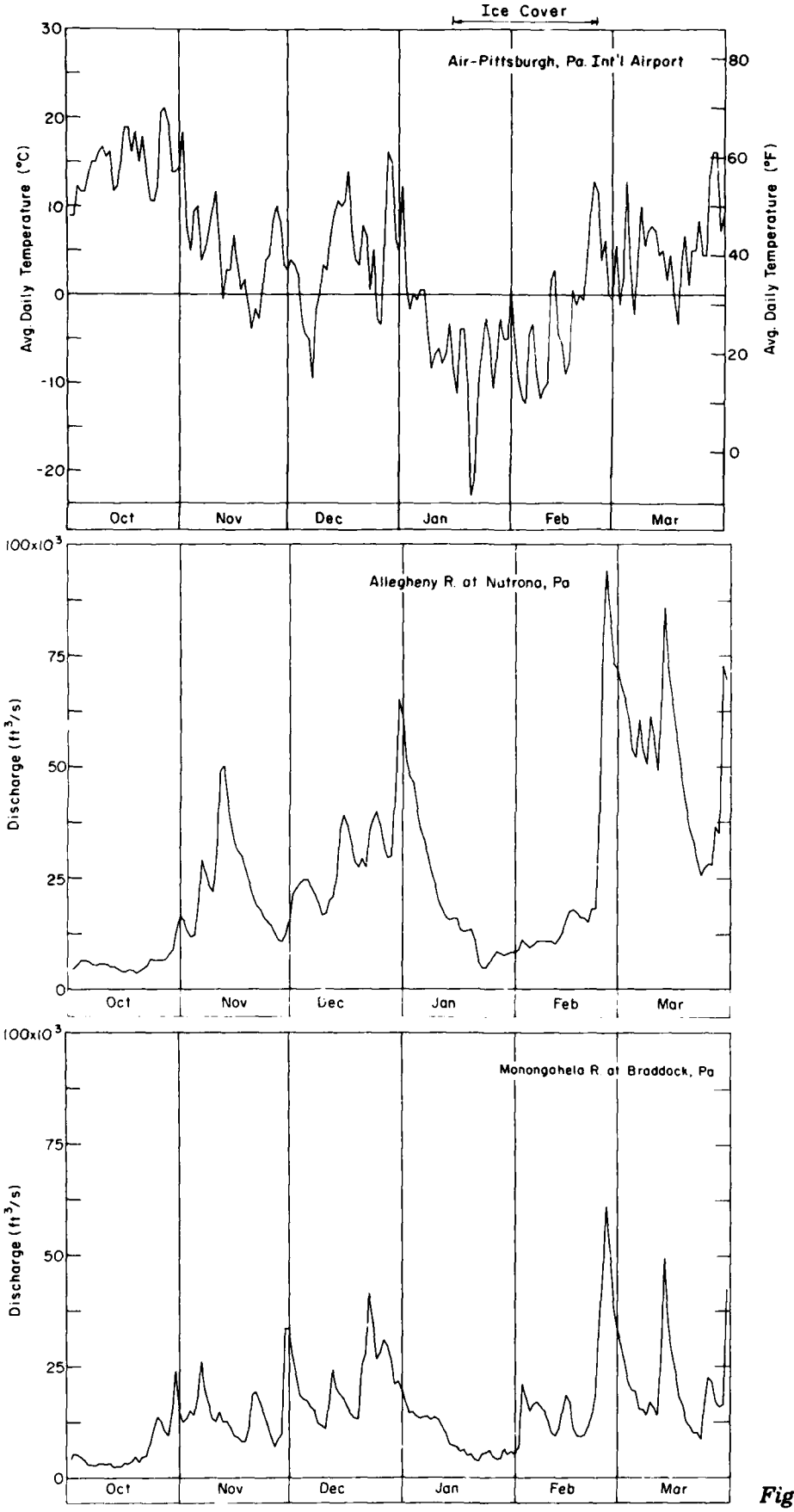


Figure E13. 1984–85.

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